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Regulation of Electromagnetic Radiation:
A Confusing Course Through Modulating E and H Waves

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A Thesis submitted to

The Faculty of

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of The George Washington University in partial satisfaction
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February 15, 1982

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ABSTRACT:

Regulation of Electromagnetic Radiation: A Confusing Course Through Modulating E and H Waves

by Major Laurent R. Hourcle

The thesis examines radio-frequency radiation from the perspective of controlling it as a regulated pollutant. First it examines the character of radio-frequency radiation including a primer as to its unusual physical characteristics. It then examines the growth in use of non-ionizing radiation and the growing but still contradictory body of scientific data as to its potential adverse biological effects. With this as a foundation,the thesis then turns to a review of the world's primary radio-frequency radiation exposure standards and an examination of the several federal agencies which may be able to regulate radio-frequency radiation and their statutory basis for doing so. The thesis concludes in recommending a limited approach to regulation based upon radio-frequency radiation's unique physical characteristics and the limited consistent data as to adverse biological effects.

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INTRODUCTION

Radiation to many people is synonymous with thoughts of a "Three Mile Island -- China Syndrome" power plant disaster, or the ominous mushroom cloud of a nuclear weapon. But "radiation" is a generic word meaning merely energy in wave or particle form moving through space or some other medium.

Radiation may be divided into two classes: "ionizing" and "non-ionizing." Ionizing radiation has sufficiently high energy to strip electrons from atoms -- the ionization process. This type of radiation drives nuclear power plants and gives nuclear weapons their destructive power.

"Non-ionizing radiation" is a term less well-known to us. Yet --in one way or another -- each of us probably makes some use of it every day. "Non-ionizing" radiation includes radio frequency radiation (responsible for radio and television broadcasts) and microwave radiation (used for radar, long-distance telephone links, ovens, and medical diathermy devices.) "Non-ionizing radiation" also includes radiation in the visible spectrum--light--the reflection of which is what we see.[1]

"Non-ionizing radiation is all around us.[2] In fact, each of us is responsible for generating minute amounts of non-ionizing radiation just by being alive. The vibration of the molecules in our bodies generates minute electrical fields; in essence, a form of non-ionizing radiation.

People have been concerned for some time about potential harmful effects of relatively low levels of ionizing radiation. Now they are becoming concerned also about possible harmful effects of low levels of non-ionizing radiation. One author wrote a series of articles in the New Yorker Magazine allegedly documenting the peril of non-ionizing radiation and a massive government coverup of that peril which were later collected into a book "The Zapping of America." In sensational tones , the cover of the book states, "Microwave radiation can blind you, alter your behavior, cause genetic damage, even kill you. The risks have been hidden from you by the Pentagon, the State Department, and the Electronic Industry. With this book, the microwave coverup is ended."

We are increasingly seeing citizens "concerned" about potential effects of non-ionizing radiation and thusly challenging sitings of various non-ionizing radiation emitters. In the relatively recent past, there have been several defense-related suits involving such emitters. One suit under the Federal Tort Claims Act alleges injuries to a contractor employee conducting tests of potential effects of electromagnetic pulse radiation on a Minuteman missile

site in Montana. In the upper peninsula of Michigan, first law suits and then political pressure appear to have been successful in stopping the Navy from installing a large very low frequency communications complex over a large area. The Air Force has been challenged in both California and Massachusetts on the installation of a sophisticated yet relatively low powered, radar to detect submarine-launched ballistic missiles. There was a suit in New York City attempting to stop the Coast Guard from installing a harbor radar surveillance network. Lastly, there is a growing number of suits alleging exposure to non-ionizing radiation as a basis for workmen's compensation claims.[3]

It has been established for some time that sufficiently intense exposure to non-ionizing radiation can cause harm. This is usually done through a "thermal" process, much like the effect we intentionally use to "cook" in a microwave oven. The damage is done by transforming the electromagnetic radiation into heat. To the extent that non-ionizing radiation damage is caused by heat, these have become known as "thermal effects."

Increasingly, however, there is concern about the possibility of so called "non-thermal" effects. Researchers in the Soviet Union and Eastern European nations have repeatedly claimed to document effects caused by radiation without sufficient energy to cause "thermal effects."[4]

At the same time we have seen a tremendous increase over the past decade in the number of man-made sources of non-ionizing radiation emitting into the atmosphere. For the most part, non-ionizing radiation now present in our environment was not there before World War II. Since then we have had an electronic revolution. Every city of substantial size in this country has a television station and probably more than one radio station. Over 30 million Citizens Band radios alone have been licensed. Radar, once the sole province of the military, is now common in civilian airplanes, vessels, and increasingly used on our roadways. Even some home intrusion detection systems are based on a radar emitter. Other emitting sources include walkie-talkies popular among the young and microwave ovens that are now common place in our kitchens.

This paper examines radio-frequency radiation from the perspective of controlling it as a regulated pollutant. First, it will examine what is "non-ionizing radiation;" and then move into a primer of its unusual physical characteristics. It will then examine the rapidly growing number of non-ionizing radiation sources and the rapidly growing but still contradictory body of scientific data regarding possible adverse affects of low level non-ionizing radiation. This background will be particularly important for understanding the complex problems of regulating, in

a scientifically logical manner, this form of "pollution." We will then examine the stringent non-ionizing radiation standards in communist countries --standards which for the most part call for maximum levels of exposure 100 to 1000 times less than the suggested maximum levels in this country. Then we will examine the current status of governmental regulation of non-ionizing radiation in this country. Here we will try to sort out the federal effort and the many Federal agencies which have programs (albeit sometimes conflicting). Lastly, we will suggest a structure for a Federal regulation program.

FOOTNOTES

1. The visible spectrum occurs at aproximately 3 x 10^{14} Hertz. Recall that in even the visible spectrum, the light that we see is comprised of a spectrum of colors, each color with a distinct frequency.

2. On a cloudless day in the temporate regions of the Earth sunlight irradiates the Earth at approximately 100 milliwatts per square centimeter cleary, S.F. et al, "Analysis of the Exposure Levels and Potential Biological Effects of the Pave Paws Radar System" National Academy or Sciences 1979 at (hereinafter NAS) at page 29.

3. Microwave News May, 1981.

4. "Thermal" versus "non-thermal" effects is more a problem of semantics -- rather than science. In the Eastern literature, thermal effects are said to occur when an effect is noted and a "measurable" change is noted in temperature. In older "whole body" experiments, this was often measured by a rectal temperature probe. This raises the possibility that while the radiation affected a certain area -- the thermoregulatory system of the body served to negate a measurable whole body temperature rise. This possibility seems particularly strong with pulsed experiments. Rapid pulsing may cause short "unmeasurable" temperature variations. Most researchers now recognize that the objective is to determine if RFR exposure causes an effect; and if so, then assess whether the effect is clinically significant. It should not matter whether the researcher has equipment of sufficient senisitivity to record the energy exchange.

Chapter I

WHAT IS NON-IONIZING RADIATION

Simply non-ionizing radiation is those forms of radiation with insufficient energy to cause the ionization process.

Figure 1 depicts the radiation spectrum.[1] Note the inverse relationship between frequency and wavelength. The lower the frequency, the less its ability to deposit the energy and the longer the wavelength. Non-ionizing radiation is usually considered to include radiation with lower frequency and (hence longer wavelengths) than ultraviolet light.

Surprisingly, for a scientific/technical discipline, there is little consistency in terminology about non-ionizing radiation and its frequencies from country to country. This causes problems when one reviews non-ionizing radiation literature from other countries. Figure 2 from Baranski and Czerski[3] shows some of these terminology problems.

This paper will be concerned with radiation from 10 to 300,000 MHz. This covers the most used portions of the microwave and radio frequency segment portions of the electromagnetic spectrum. For convenience this part of the spectrum "radio frequency radiation" will be referred to as "RFR." Included in these frequencies are the emissions of standard transmitters for AM and FM radio and UHF and VHF television, most radars, CB, amateur radio, and microwave ovens.

Electro-magnetic waves as their name implies have two parts: an electrical component (or wave) which is measured in volts per meter (V/M) (abbreviated as the "E" component) and a magnetic component measured in amps per meter (A/M) (abbreviated the "H" component). Figure 3 shows what a simple form of a continuous electromagnetic wave would look like in the far field. One complete oscillation cycle of the E and H compenent of the wave equals the wavelength, usually abbreviated by the Greek letter lambda.

When dealing with electromagnetic fields, researchers have historically discussed the amount of radiation present in terms of its "power density"[4]. This is the wattage (a measure of power) as applied to an area of surface. For example, the power density exposure standard usually used in the United States is 10 milliwatts per square centimeter or abbreviated $10mW/cm^2$. The well publicized Soviet irradiation of the U.S. Embassy in Moscow averaged less than 2 microwatts per square centimeter ($2uW/cm^2$) as measured near the windows of the Embassy[5].

Discussing the U.S. Embassy in Moscow introduces another concept. When dealing with fields of electromagnetic radiation, it's important to know where one is in relation to the source of the radiation. The power density readings just mentioned were taken at the windows of the embassy. As a general rule, the strength of a "beam" of radio frequency radiation decreases markedly over distance. The "strength decrease" of radiation in the "far field" is nearly at an inverse square ratio[6]. That is, as one moves twice the distance from the source of the radiation, the strength of the radiation (as measured in W/cm^2) declines by the square of the distance (a factor of four in this case).

This is demonstrated in Figure 4 showing the fall-off rate expected as one moves away from the RFR source and in Figure 5 graphically as one moves away from a small leak in a microwave oven.

Near and Far Field

Another complicating factor in discussing possible adverse effects of RF radiation is the difference between the "near" and the "far" fields. We noted earlier that a characteristic of RFR is that it has both an E and H wave component. In the far field the E and H components are always right angles to one another (as depicted in Figure 3). But this does not hold true for the near field. In the near field the waves are still being formed. The E and H components may vary greatly in magnitude as compared to one another in the near field. This makes estimates of strength (power density) both very complex and yet somewhat meaningless because of the changing nature of strength at places in the near field[7].

To get a true estimate of radiation strength in the near field one has to measure both the electric and magnetic wave components of the radiation. This is somewhat difficult at this time with all but the most sophisticated instrumentation.

Power Density and Specific Absorbtion Rate

So far we have talked about the strength of RFR in terms of power density: that is, in the far field, how strong is the E field component; and in the near field, how strong are the combined E and H fields. But in dealing with concerns about biological effects, the key question becomes not how strong is the RFR (although that certainly is is a factor); but more importantly, how much of the RFR energy is actually absorbed into the biological tissue and how that absorption takes place. The question of "how much energy is absorbed?" is answered in terms of the specific absorbtion rate (SAR). Specific absorption is defined

as the quantity of electromagnetic energy in joules that is absorbed per unit of mass of an absorbing body[8]. This is usually expressed in joules per gram or kilogram (J/g or J/kg or millijoules per gram) (mJ/g). "Specific absorption" equals total dose of energy received. The "specific absorption rate" adds a time element. It is defined as the quantity of electro-magnetic energy absorbed per unit of mass over a set period of time. It is expressed in either watts per kilogram (W/kg), or milliwatts or watts per gram (mW/g or W/g.)[9]

Important to remember is that SAR is an "electrical" not a "thermal" phenomena. SAR is a manner of comparing absorbed energy --not merely heat. Thus, SAR comparisons are important when discussing "non-thermal" effects at various power densities. The SAR becomes important because RFR is not absorbed by all parts of the body in a completely consistent ratio to the RFR field of energy.

Just how much RFR is actually taken in by a biological being (either experimental animal or human being) depends on many variables. These include the dialectric and thermal properties of the tissues involved and several factors involving geometric attributes to the body (e.g. size, shape and relative position of the body to other objects including the RFR emitting source.)

Biologic Antennas and Resonant Frequencies

So far we have cursorily discussed, what is RFR, how it is created, and transmitted. But the potential for adverse health effects, about which we are concerned, comes when the RFR is received. A human being--and even his various biologic parts (e.g. arms, legs, eyes)--act in some ways like an antenna. Just as an antenna can be made a certain size to be "tuned" to maximize reception of certain frequencies, so due to the size of our bodies and their parts, we are "tuned" to receive some frequencies better than others. Those frequencies which our bodies (or their parts) are tuned to receive are called resonant frequencies.

Antennas are most efficient at "receiving" frequencies with wavelengths that are about twice of the length of the antenna element. Figure 6 depicts this using the whole body as an antenna. This means that things of different sizes are "tuned" to different frequencies. A National Academy of Sciences[10] report computed the following resonant frequencies for various whole human body sizes[11]:

SIZE	FREQUENCY	FREQUENCY USE
70 kilogram (154 pound) 1.75 meter (5'9") man	65.2 MHz	Television Channel 3
32.2 kilogram, 1.38 meter (4'6 1/2") child	82.6 MHz	Television Channel 6

One obvious concern here is that most older biological experiments done in this area have involved irradiation of relatively small laboratory animals (e.g. mice, rabbits,) at 2,450 MHz, the frequency used in microwave ovens. This frequency is substantially nearer to the resonant frequency of small research animals than it would be, for example, to man. If a particular biological effect is found in a lab mouse from radiation at a given frequency, the question then becomes whether the effect may be caused by that particular frequency; or whether it is caused by the power of the RFR, as the frequency may be resonant to the research animal as measured in the amount of energy captured by the biological entity (SAR). The health evidence may not be directly transferable to man. Rather, the scientist would have to "scale" to what would be the corresponding resonant frequency for a human being, or a corresponding level of energy deposition (SAR).

Hot Spots

Another problem for RFR researchers is "hot spots." This describes areas, where, a concentration of energy deposition occurs[12]. These concentrations can be an order of magnitude greater in SAR than normal. One researcher reports that under the right conditions an ankle may have a local absorbtion rate 26 times that calculated for the body as a whole.[13]

Ground

Merely having a man grounded to a high conductivity plane may increase whole body absorption of his resonant frequency by a factor of 2 as opposed to an individual not similarly grounded. So, too, is there a change in the resonant frequency for the grounded as opposed to the non-grounded subject. The new resonant frequency will be about half that for the non-grounded subject. Consider Figures 7 and 8. Note how both different parts of the body have different specific absorption rates for the same frequency and how one part of the body may be more "susceptible" to a certain frequency than another part of the body. Note, for example, how the head in both charts displays a series of peak specific absorption rates and not just the classic bell-shaped curve favoring one frequency with a gradual decline from both sides of that frequency.

Reflections

Absorption rates may be increased by factors of from 5 to 20 when bodies are merely in proximity to highly conductive (metallic) surfaces (either flat or at a 90 degree corner.) So, too, localized field strengths have been reported to increase by factors of from 5 to 10 in rooms where radiation may enter through windows and be reflected off walls[14]. Even proximity to another biologic being might as much as double the specific absorption rate under laboratory conditions.[15] Also, there appears to be a reflection phenomena within the body itself. For example, as noted in Figures 7 and 8 the resonant frequency of the human head is somewhat different from the resonant frequency of the whole body. One commentator has noted[16] a difference in resonant values between that of an intact (connected to the body) human head from values determined for an isolated (separated) model of the head.[17] However, the researcher goes on to indicate that there is no difference between the isolated model and the intact heads in the way the RFR was distributed within the head area. Figure 9 and 10 show "typical variations of localized field intensification found in figurine scale models."[18]

Polarization

We have already seen that one characteristic of RFR is that it has both an E and an H field component. Another important consideration when dealing with specific absorption is the position of the receiving object (e.g. human being, animal or simulated model test subject) relative to the E, H or K planes (K is a direction of propagation.) Tests have indicated that RFR is received more efficiently (i.e. therefore, has a higher specific absorption rate) if the receiver is aligned with its longest dimension parallel to the E field.[19] There are similar but lesser peaks of absorption efficiency where the subject is aligned parallel to either the H field or the direction of propagation (K).

Another phenomena is that polarization may also result in a change in the resonant frequency. The resonant frequency for a subject polarized parallel to E field occurs when the length of the subject is approximately .36 to 0.4 times the waves length of the radiation. Where the subject is aligned parallel to the K or H fields, then the resonant frequency occurs when the "weighted average circumference" of the subject is approximately half the wavelength.[20]

Composition of the Irradiated Object and Wavelength

An interrelated issue in determining possible health effects from RFR involves wavelengths and the substance being irradiated. Non-ionizing radiation probably will not be able to penetrate completely a human being. The

depth of the penetration depends on both the frequency, enegy level, and, in part, on just what is being irradiated. That is, RFR passes more easily through some substances than others.[21] Perhaps the simplest way to describe this is to examine what happens when RFR strikes and starts passing through a biological organism.

As soon as the non-ionizing radiation strikes the surface, its energy starts being absorbed and reflected. As absorption takes place, the amplitude of the wave decreases (attenuation) and phase shift takes place. The wavelength and energy are reduced steadily as it passes through the tissue.[22] The so-called depth of "penetration" is reached when the wave's energy decays to 37% of the power density it had just after it entered the surface of the organism. At this, point 87% of the RFR energy has been dissipated.[23]

This describes the effect in a simple model when there is only one type of tissue (with a given conductivity) involved. People, however, are made of layers of tissue (e.g. skin, fat, muscles) all with different conductivity. Additionally, when media (such as tissue) with different dialectric properties meet (e.g. where fat meets muscle) there are perturbations in the electrical field. One example is the creation of standing waves which cause sudden concentrations in the field strength of the energy at the interface point.[24] Figure 11 redrawn from Baranski and Czerski demonstrates both how different frequency waves are attenuated and also the phenomena of energy discontinuity at the interface of two substances.

The attenuation phenomena further complicates research done with smaller animals. Attenuation is principally a function of how far the energy penetrates an object. Therefore, when RFR experiments are done with small animals, the RFR can reach organs that it might not otherwise be able to reach in a larger animal (e.g. man). The entire brain of a rodent is probably within an inch or two of the surface where the radiation enters, yet in a human being there might be three, four or more times more material that would have to be penetrated (with the radiation constantly losing strength) to reach the far side of the human brain.[25] Tables 1 and 2 taken from Baranski and Czerski show the various depths of penetration for various frequencies. (Note that in Table 2 the figure for the wavelength in tissue of 100 MHz RFR is in error).

Instrumentation and Dosimetry

Historically, there have been two problems in this area. One has been in developing equipment sufficiently sensitive to make readings of low level and near field

RFR, and the second problem has been to design test instruments that do not (from their own design) throw off test results.

We have seen how RFR absorption can be influenced by changes in the shape, position, and composition of the biologic entity. It appears that in many older cases, the test instruments themselves either caused changes in absorption or at least caused biased test results.

Many older experiments involved use of conductive leads and other metallic components and sensors implanted in the bodies of test animals. These can cause a several fold increase in the specific absorption rate in adjacent tissue; therefore, they lead to more RFR energy being absorbed than otherwise would have been, and hence, possibly biological effects that would otherwise not reasonably have been expected from a similar power density of radiation. Another problem is that metallic leads from a sensor on the animal to the test instrument may either leak energy (possibly adding to the reading) or more probably in some way receive (and be influenced by) energy from the RFR emitter. In many older experiments, researchers failed to understand erroneous test readings which lead to faulty experimental conclusions.[25]

More recently instruments have been developed to minimize effects they otherwise might have on readings. One of the new type instruments uses a crystal sensor connected with fiber-optic leads. These materials are largely electrically transparent.[27] Another of the new sensors uses leads of carbon-impregnated plastic. These leads have very high electrical resistivity to minimize energy leakage and perturbations of the electromagnetic field.[28]

Much of the work already discussed was based on various modeling techniques using other than biologic substances to replicate the electrical characteristics of biologic tissues.[29] Increasingly, researchers have taken the next step in reducing their findings to numerical formulas for computer modeling.[30]

Scanning-infrared thermography has also been used to study distribution of RFR in both animal and human models and sacrificed research animals. This latter technique involves sectioning the model or animal[31], exposing it to RFR (from the unsectioned side), and then immediately measuring the temperature distribution on the sectioned side.[32] The reason this method cannot be used as the definitive study of absorption is because absorption--at least to the extent it results in a heating effect--has that effect reduced by the thermoregulatory system of the body. There is obviously no thermoregulatory system in a sacrificed research animal. Hence, this type of test is valid only to the extent it shows RFR distribution in the body.[33]

Another problem has been adequate equipment to measure RFR in the near field. This is where the intensity of RFR should be strongest and, hence, have a potential for biologic effects. It is also usually the area where workers would be exposed to RFR (i.e. occupational exposure). Particular problems are involved in measuring the near field due to its complex RFR environment with complicated multifrequency, multipath, multimode, electric and magnetic fields.[34] There are also problems in measuring pulsed fields of energy. Only the most sophisticated equipment currently available has reaction times fast enough to measure the highs and lows of a rapidly pulsed RFR field, such as one might find in a radar unit.

But perhaps the biggest equipment drawback in studying human effects of RFR is that there is nothing in the way of an RFR dosimeter to record a person's day-to-day accumulative exposure multiple frequencies to RFR.[35] In dealing with nuclear energy, the standard technique is for the subject to wear a dosimiter so that the subject's later total exposure to that form of radiation may be measured. Lack of a dosimeter competent to measure the typical low levels of RFR in the environment is perhaps one of the biggest problems in conducting valid epidemiological studies of RFR radiation. Such a study would have to measure and then compare the radiation received by both control and subject groups. However, as already noted, RFR is particularly subject both to being blocked and also to being multiplied by reflections. Without a dosimeter it is almost impossible to know with any degree of certainty how much RFR the subject group had received as compared to the control group. Even then, an RFR dosimeter would have to be particularly complex because of the need to deliniate the type of RFR (e.g. frequency, mode (continuous wave or pulse), etc.).[36]

FOOTNOTES

1. Van Nordstrand's Scientific Encyclopedia, 1964 edition.

2. Stanislaw Baranski and Przemyslaw Czerski, The Biological Effects of Microwaves, 1977, Dowden, Hutchinson and Ross, Inc. Strausburg, PA (hereinafter Baranski and Czerski) at 12.

3. *Id*. at 13.

4. In the far field power density is a measure of only the E component strength.

5. Foreign Service Health Status Study, Evaluation of Health Status of Foreign Service and other Employees from Selected Eastern European Posts, Department of Epidemiology, School of Hygiene and Public Health, the Johns Hopkins University, 1978 (hereinafter Johns Hopkins) at 2. 1,000 microwatts equal 1 milliwatt. Comments of J. Mitchell, USAFSAM/RZP October 1981. It should be noted that thorough study found no evidence of the Soviet irradiation causing adverse biological effects on those working and living at the Embassy. The Soviet motive for the irradiation remains unknown. It may have been no more than to know that its discovery would cause dissention and lower morale among U.S. personnel in Moscow. It nonetheless remains one of the more famous incidents in the history of RFR exposure.

6. A Technical Review of the Biological Effects of Non-Ionizing Radiation, a report prepared for the Office of Technology Policy by an Ad Hoc working group, May 15, 1978, Office of Science and Technology Policy, Executive Office of the President (hereinafter Technical Review) at Appendix B page 3. For systems that emit RF energy from a large surface, the power would dimish in a direct ratio to distance close to the system.

7. Baranski and Czerski, *supra*, state:

> A very important restriction must be kept in mind. Such a simple wave is formed only at a certain distance from the source. At smaller distances within the inductive field, E and H may be shifted in phase. The magnetic field is in phase with the current in the antenna and the electric field with the electric charges on it. An energy flow back and forth between these fields may occur. The electric and magnetic components do not show simple proportionality and should be measured separately. In view of this, a far-field zone and a near-field zone should be distinguished. More complicating phenomena may occur. Multipath interference, reactive

near-field components, interaction between the source and nearby objects, complicated modulation of the field, polarization, and, in the case of irradiation of biological objects, subject-source coupling, make the usual dosimetry of microwave exposure questionable in many instances.. .. Here it suffices to say that the universally accepted quantification of microwave exposure (measurement of incident radiation in relation to observed bioeffects) by measurement of the mean power density is not valid for the near field zone is somewhat of a simplification in many other instances. (at 30-31)

8. Technical Review, supra, Appendix B, Page 4.

9. Technical Review, supra, Appendix B, Page 4. According to the authors of the Compilation and Assessment of Microwave Bioeffects, A Selective Review of the Literature on Biological Effects of Microwaves in Relation to the Satellite Power System," (1978), Pacific Northwest Laboratory, specific absorption rate is being considered by the National Counsel on Radiation Protection and Measurements as the official method for expressing those rates. (Appendix B, Page 6). Specific absorption rate is the premise for the "curve" in the currently-proposed revised ANSI standard for non-ionizing radiation. Similar "curves" appear in both the proposed revision of the Air Force standard and the proposed NIOSH criteria document.

10. NAS, supra, at page 45. Admittedly relating resonant frequency solely to height is something of a generalization. There are other factors beside length which can influence resonant frequencies.

11. NAS, supra, at page 46. The formula is $f_r = (11{,}400/L_{cm})$MHz. According to the definition in Technical Review, electromagnetic waves are seldom, if ever, absorbed uniformly by a biological body. Concentrations of energy will occur that are called electrical hot spots. If the field is sufficiently intense to overcome local cooling by the thermo regulatory system, thermal hot spots may also occur.

12. Richard Tell, "Technical Note, "An Analysis of Radio Frequency and Microwave Absorption Data with Consideration of Thermal Safety Standards," U.S. Environmental Protection Agency, (1978), at page 12. Tell restates the calculations and projections of Guy: a 70 kilogram, 1.74 meter height standard size man who is frontally exposed to radiation of 31 MHz has an estimated whole body specific absorbtion rate of 5.8 microwatts/kg but the ankle absorption rate would be 149 microwatts/kg with a neck SAR of 29.6 microwatts/kg. More recent investigation in this area indicates

that these "hot spots" phenomena tend to be defused by the thermoregulatory system of a living being.

13. NAS, supra, at 47. However, recent research indicates that in a living, moving, biological entity, these high levels of energy, as measured by SAR measurements, are averaged greatly downward by differing positions (i.e. bodily movement of the affected part) and the operation of the thermoregulatory system. (Conversation with John Mitchell USAF/SAM, October 23, 1981.)

14. NAS, supra, at 50.

15. NAS, supra, at 50, cf. Tell--at 18.

16. Tell, supra, at 16.

17. 350 MHz vs. 450 MHz.

18. Tell, supra. Note that Figures 9 and 10 cannot be used as a complete comparison of the difference between the grounded and the nongrounded subject because the wavelengths (and hence the frequencies) of the radiation are different.

19. Id. at 13.

20. NAS, supra, at 45.

21. Id.

22. Id.

23. A properly-sized wire mesh can be a complete barrier to RFR. This was the technique used at the U.S.'s Moscow Embassy to counter Soviet RFR irradiation.

24. Baranski and Czerski, supra, at 47.

25. Id. at 47-48.

26. Cleary, S.F., "Biological Effects of Microwave and Radio Frequency Radiation," CRC Critical Reviews in Environmental Control, (1977) at 155.

27. The brain may not be the best example, because there is a hot spot phenomena associated with it. Precisely where that hot spot occurs appears to be a function of size and frequency, see Baranski and Czerski, supra pages 57 to 58 and Tell, supra pages 7 thru 9.

28. Technical Review, supra, at 37.

29. Baranski and Czerski, _supra_, page 62, Technical Review _supra_ at 39.

30. _Technical Review_, _supra_ at 39.

31. _Id_, and Baranski and Czerski, _supra_ at page 60.

32. Baranski and Czerski _supra_ describe the process for using test animals: "Essentially the same technique may be applied to test animals. . . the animal sacrificed and frozen in dry ice, or liquid nitrogen in the same position as used for exposure. The body is cast in a polyfoam block and dissected in a plane parallel to the applied source. A thin plastic film is applied to prevent moisture evaporation. The animal is brought to room temperature, irradiated and thermographic records are made. (This is similar to the procedure used with phanton models.)

33. _Technical Review_, _supra_, at 41.

34. _Id_.

35. Testimony of Dr. Parr, June 28, 1977, before the Senate Committee on Commerce, Science, and Transportation, Senate Report 49, at page 597.

36. _Technical Review_, _supra_, at 44.

37. Testimony of Dr. Setlow before the Senate Committee on Commerce, Science, and Transportation, June 29, 1977 Id. at 753.

38. _Id_.

CHAPTER II

EXPOSURE TO RFR

Types of exposure

It is easiest to think of exposure to RFR in categories. First is occupational exposure: the type of exposure that occurs to workers near RFR emitting equipment. In a work environment, exposures are dominated by the RFR emitters in that work place. The second category of RFR exposure is that incurred by the general population. As will be discussed, this comes fairly equally from a number of contributing RFR sources. As such, the general population is exposed to an RFR field that is complex in terms of contributing frequencies, field strengths and other characteristics.

As noted earlier, wide-spread exposure to man-made RFR is a relatively new phonemena; and one - as measured by the number of sources - which is increasing rapidly. The Office of Science and Technology Policy Technical Review[1]; finds that there has been a proliferation of RFR sources:

> During the last 50 years, the use of the RF spectrum has grown enormously and has become an integral part of modern society, providing many valuable services to mankind in the form of communications systems, navigation, broadcasting, radars, industrial processes, consumer products and medical applications.
>
> . . .
>
> The growth in RF sources represents significant economic investments. During 1976, sales of communications and electronic products total $38.9 billion, an increase of $11.1 billion since 1971. Of this total about 48 percent went into the communications and industrial market, 34 percent into the government market; and 18% into the consumer-product market. The current estimated U.S. government depreciated capital investment in electronics is $67 billion and expected to grow to $99 billion by 1986.[2]
>
> The consumer has contributed heavily toward the growth of the electronics industry and the introduction of RF sources. The number of microwave ovens in operation as of January 1970 was estimated about 50,000 units. In 1971 it was predicted that sales of microwave ovens for the home, during 1975, would reach 200,000; actually in 1976, 1.6 million ovens were sold. There has been an unanticipated explosive growth in consumer demand for citizens band (CB) radios in recent

years. There are approximately 30 million CB's currently in use, operating in the high frequency (HF) band with maximum authorized radiated power of four watts. Estimates have been made that 4 to 5 million sets were sold in 1975, and that sales would double during 1977.[3] It should be noted that the public is increasing its demand for more frequency spectrum and consideration has been given to the allocation of additional frequencies, possibly even in other bands. NIOSH estimates that over 35 million industrial RF sources are now in use.

Commercial and governmental demands for, and uses of, communication products remain strong. The establishment of domestic satellite communications systems, increased use of mobile radio and increased demands for traditional services such as broadcasting, are but a few examples of why the communications market continues to expand. The Federal Communication Commission (FCC) as of 1977 had authorized over 9 million transmitters. In the U.S. Government sector, there have been over 144,000 radio-frequency assignments as of 1978. It must be recognized that one assignment may represent hundreds or even thousands of individual transmitting devices. For economic reasons, there has been a marked increased in the utilization of point-to-point microwave transmissions via relay towers or satellites for conveying large quantities of voice, video and other information. Two-way mobile radio services, (450-512 MHz) have undergone dramatic growth. Virtually every type of business and industry has viewed this type of rapid-communication service as a vital management tool. This type of communications has also been important in improving the delivery of medical care and for environmental and safety services. The FCC has recently authorized new frequencies in the 806 to 947 MHz range for land-mobile use. Growth also continues in public broadcasting. As of May, 1978, there are 369 UHF-TV and 624 VHF-TV stations. Demands for radio services have been particulary strong, and there are now 4,524 AM stations and 3,957 FM stations, an increase of 150 (3.4%) and 1388 (87.2%), respectively, between 1971 and 1978.

General Environmental Exposure

Starting in 1975, the Environmental Protection Agency (EPA) undertook an effort to determine to what extent the

population of the United States is exposed to radio frequency radiation. EPA's effort centered on development of a mobile monitoring van to measure levels of radio frequency radiation in areas around the country.

EPA outfitted a mobile van with several different types of antena systems to cover several RFR bands of interest. The antennas fed to a scanning radio frequency spectrum analyzer. Data is then entered into a mini computer (which also controls the spectrum analyzer). The antennas are calibrated indirectly to a set of National Bureau of Standards calibrated antenas. The seven frequency ranges monitored by the van are as follows:

Frequency (MHz)	Use
0 to 2	VLF communications and standard broadcast
54 to 88	low VHF television broadcast
88 to 108	FM broadcast
150 to 162	VHF land mobile
174 to 216	high VHF television broacast
450 to 470	UHF land mobile
470 to 806	UHF television broadcast

Obviously it is not possible for the van to measure RFR at every place in the United States. The EPA staff drew some assumptions. The prime one was that cities, with their concentration of emitting devices, are more likely to have higher readings then rural locations. Therefore, measuring in the cities, EPA thought, would give them a good initial feel for the seriousness of the problem. Fifteen major cities were chosen representing a 1970 population of over 44 million people. One important factor assisting the EPA study was detailed, machine processable, census data for the entire United States. The 1970 census established specific geographic areas or cells known as Census Enumeration Districts (CEDs) and provided the geographic coordinates of each CED. There are some 257,000 CEDs in the United States. In urban areas CEDs are relatively small in geographic size due to the cities' higher population density. EPA developed a system for selecting a number of CEDs within a city as representative of that city's population. An additional feature of EPA's system was a weighting factor to ensure that CED's with greater populations have an increased chance of being selected as a measurement site. In each of the surveyed cities, between 30 and 40 CEDs were randomly selected for measuring. Over the course of approximately two weeks the measuring van visited and measured at, or as close as possible to, the geographic center of each CED. Tables 3-5 present the results of EPAs measurements in the fifteen selected cities.[4]

In all, the EPA studies found (after discounting radiation below 54 MH because of its inherent low energy) that persons at ground level of these cities, on the average, were exposed[2] to .005 microwatts of RFR per square centimeter (.005 uW/cm^2). Persons in New York City could expect the highest median exposure--but that was still only .0022 uW/cm^2. Just over one half of one percent of persons in the fifteen US cities surveyed were exposed to more than 1 uW/cm^2 of RFR. (Of the fifteen cities, Washington, D.C., had the highest percentage of persons exposed to more than one microwatt of RFR but that was still only 2.8%).

One caveat to the measurements made by the van was that they were taken at a height of less than 20 feet (the maximum extension for antennas on the measuring van.) As part of the studies, however, the EPA used portable equipment to measure RFR levels at taller buildings in close proximity to RFR emitting sources. These were thought by EPA personnel to be areas of potentially more serious exposure conditions, because of the pattern of radiation from most broadcasting antennas. These antennas tend to beam their signals (or radiation) out and over nearby ground areas. The assumption, which proved to be correct is that as one moved up a tall building located near a major RFR emitter, one would see a higher RFR radiation level than at ground level near the antenna. (See table 4). Particularly interesting are several readings in a tall Miami building, located close to a major FM emitter. One can see the radiation increase steadily as the measuring site moved from the 26th floor to the roof of the building. This phenomena, however, appears to hold true only at those measuring sites in close proximity (a few hundred feet or less) to a high power RFR source. The upper floors of tall buildings located at some distance from broadcast antennas do not have a similar differentiation between measurements made at ground level and those made at higher points in the building.[5]

Specific Source Environmental Exposure

EPA has begun to characterize two types of non-occupational RFR environment. The "general environment" is subjected to no one particular RFR source. The "specific source environment" occurs where the RFR readings are dominated by one emitter. EPA now intends to focus its future measuring activities in specific source environment area.

EPA's staff preliminary concluded that "radar" type sources normally do not contribute significantly to the general radio frequency environment, apparently because their beams are highly directed and are located either high above ground or angled above the horizon. In studying San Francisco, the EPA team found that at the largest value of power density, radars added only .001 mW/cm^2 to the accumulative RFR levels in the area.[6]

Another phenomena occurs with some types of FM antennas which in addition to the normal "up and out" form of beam also have an RFR beam perpendicular to the tower. In such cases, fields of up to 350 microwatts have been measured at ground levels in areas that were accessible to the public. In one, as yet unduplicated finding, readings were recorded at the base of an FM tower for several emitters on Mount Wilson, California ranging between 1000 and 7000 uW/cm^2 1-7 mW/cm^2.[7] (The higher ratings though, may have been caused by proximity to conductive structures.)

Microwave communications links commonly used for long distance telephone circuits work at relatively low power. Maximum power density of these devices is calculated to be about 700 uW/cm^2. However, this occurs at areas inaccessible to the general public. The maximum values recorded near these units at ground level by EPA personnel were less than 1 uW/cm^2.

Radars used by police to measure the speed of passing autos have a power of only about .1 watt. The maximum calculated power density for typical police radars ranges from 170 to 400 uW/cm^2 decreasing to less than 24 uW and .2 uW/cm^2 at distances of 3 and 30 meters, respectively, moving away from the front of the units.

Another group of low power sources with which the public is having increasing contact are those in the "personal communication" area. These include both CB and other mobile/ radios and also hand-held "walkie talkies." Many of these sources radiate close to the operator. The potentially worse offender is the "walkie-talkie" with a beam radiating from an antenna essentially next to the operator's head. Because these sources radiate so close to the operator, normally the operators are in the "near field" making accurate radiation assessments difficult. In most reported studies, only the electrical component of the RFR has been measured. Further complicating the situation is that impedance of near fields is not, in general, 377 ohms (normal impedance in free space). Some researchers have attempted to define an "equivalent" free field power density by assuming the impedance value for free space and calculating the power density.[8] In one study, electric fields 12 centimeters (approximatley 3 inches) from an 2.5 watt walkie talkie operating at 27.12 MH were measured to be as high as 205 volts per meter for an "equivalent" power density of 11 mW/cm^2. In this case the magnetic field was also measured at .9 amps/meter which in turn leads to an equivalent power density of 31 mW/cm^2.[9] In reporting the results of these tests, the National Academy of Sciences cautioned that "equivalent" in this case does not necessarily mean an equivalent heating power density. For example, one study predicted that a 6-watt, 150 MH$_z$ hand-held transmitter with an antenna positioned .5 centimeters from the eye

increased the temperature in the region of the eye less than .1 degree C. That study made its prediction based on tests with prolate spheroid models of human heads.[10]

Several tests have also been run on electric field strengths in and around radio-equipped vehicles. Certain of these findings are summarized in table 6. Those transmitters operating in a frequency around 27 MH_2 are CB radios.

Occupational Exposure

In its "Technical Review," the Ad Hoc Committee of the Office of Science and Technology Policy noted that the National Institute for Occupational Safety and Health (NIOSH) has estimated that 20% of the United States work force would be exposed to industrial RFR in the work place in 1980 and that as of May 1978 there were over 35 million industrial RFR sources in use. RFR in the work place can cause two types of problems. One type of problem we will not address is a possibility stemming from increasing use of electronically controlled equipment, that one RFR field could cause another piece of electronically-controlled equipment: to malfunction either immediately in, or near to, the work place.

The second type of problem is the potential for adverse health effects from RFR leakage. Microwave medical diathermy machines have been considered for regulation for some time. According to the Food and Drug Administration (FDA), an estimated 15,000 machines are currently in use in the United States with a frequency of use per machine from 1 to 12 times per day. FDA studies indicate that the machines may produce radiation exposure densities of up to 30 mW/cm^2 in parts of the patient's body not being treated, as well as to operators[11].

Microwaves are also inceasingly used for industrial heating and drying. Table 7 is a table provided by Jaynes showing measurements of two synthetic fiber dryers used in the texile industry, an RFR "gluer" of the lumber industry and seven heat sealers in the plastics industry. The readings of field strength are readings in the "near field."[12]

Doctor Elliot Harris, Director of the National Institute of Occupational Safety and Health, Division of Biomedical and Behavior of Science, in testimony before the Senate Commerce, Science and Transportation Committee stated that near field surveys discovered that 75% of workers using RF sealings and heating equipment were found to be exposed to RF radiation levels higher than the present occupational exposure guide lines.[13]

Solar Power Satellite (SPS)

Uses for radio frequency and microwave radiation continues to increase. One of the more interesting proposed uses has been the solar power satellite program proposed by the Department of Energy and NASA.

As most recently structured the program envisioned construction of several five gigawatt (5 billion watt) electrical generating stations orbiting in space. The stations would use solar cells to convert the sun's radiant energy into a form suitable for beaming to earth. At this time either a laser system or a microwave system is envisioned for this purpose, with use of microwaves receiving primary consideration. SPS was the subject of considerable discussion in hearings before subcomittees of the US House of Representatives Committee on Science and Technology in April 1978. Additionally, a preliminary SPS environmental assessment issued by the Department of Energy (DOE) focuses on use of a 2450 MH microwave beam as the method for sending electric power from the satellite to an earth receiving station. The solar power satellite is under consideration by DOE as a method of producing a sizable portion of base load electric power in the 21st century.[14] The size of the proposed program was impressive. It is estimated that 20 to 25 of the satellites could have provided all the electric energy that was used in the United States in 1975.[15]

Under the proposal, the energy would have been received on earth by a receiving antenna (rectenna), measuring 13 by 10 kilometers (8½ by 6 miles in size). The rectenna would collect 96% of the SPS energy reaching the earth.[16] The most recent SPS concept calls for the initial rectenna to be built in the Mohave Desert.

Power densities near the satellite would have been high. The preliminary environmental assessment (PEA) estimated that workers on the satellite near the transmitting ray could be subjected to exposures as high as 3,500 mW/cm^2. At the center of the beam reaching earth, the SPS transmission would have had a power density of approximately 23mW/cm^2. However, it was preliminarily estimated that these density levels could reach as high as 100mW/cm^2 if there was a rectenna malfunction. At the edge of the rectenna, the power levels would be appoximatley 1 mW/cm^2.[17]

Another unique aspect of SPS is that the radiation from a pillar-like beam from the satellite to the ground exposes all that flies in its path. DOE is, therefore, also concerned about the effects this beam of microwave radiation might have on wildlife and also various, less obvious, atmospheric effects it may have. In their environmental assessment, they list a number of potential SPS

beam effects on both man and his eco system. To each effect they ascribe both a probability rating and a severity rating.[18]

In many ways the satellite power system exemplifies many of the difficult choices facing planners with respect to radio frequency and microwave radiation. This form of radiation can be extremely helpful to man. In SPS it provides a way of tapping a seemingly limitless source of power, while at the same time eliminating the adverse effects to the atmosphere from burning large quantities of pollution-generating fossil fuels or generating substantial amounts of potentially hazardous nuclear waste. But at the same time, SPS presents many of its own unique environmental questions.

Increasing Usage of RFR

While SPS was one of the more specactular uses of radio frequency radiation, the more common uses are also increasing. For example, the Federal Communication Commission is currently considering granting licenses in two new mobile communication services. They estimate that these two services alone over the next 10 years will cause an increase of several million transmitters at a cost of more than a billion dollars. The FCC also now has pending before it several new uses for the 900 MHz band (more particulary the band ranging from 806 to 947 MHz). One is for an electric utility load management system which envisions a link possibly reaching every home in the country. Another is for three new voice paging networks supporting a potential half million new paging users. Yet another proposal is a two-way digital paging service which would start with 25,000 hand-held units. There is also a proposal for a new personal (non-business) radio service estimated to attract 1 to 10 million users.[19]

FOOTNOTES

1. Technical Review, supra, at p.p. 13-16.

2. There is no mention as to whether these statistics are adjusted for inflation.

3. Citizen Band radios operate in the frequency of approximately 27 MHz with a power output of not more than 4 watts. The "CB" boom has peaked, the FCC currently lists some 9,820,000 licensed CB stations. A station may represent more than one operator and more than one transmitter (e.g. one station could have a home base station and one or more CB equipped vehicles.) (Conversation with John Small, FCC Private Radio Bureau Oct. 28, 1981).

4. United States Environmental Protection Agency, Radio Frequency Radiation Levels and Population Exposure in Urban Areas of the Eastern United States, EPA-520/2-77-008, (1978), at pages 2 to 3; Proceedings of IEEE Vol 48. January 1980.

5. Interview with David E. Jaynes, Jr. April 3, 1979.

6. Office of Radiation Programs, United States Environmental Protection Agency "Population exposure to VHF and UHF broadcast radiation in the United States", ORP/EAD 78-5, (1979).

7. Interview with Jaynes.

8. NAS, supra, page 37 to 39 $S(W/m^2) = E^2(V-n)\ 2/377$ ohms.

9. In one other test a 1.8 watt hand-held unit operating at 164.45 MHz resulted in a field measurement of 200 nanojoules per cubic meter (or equivalent of 11.9 miliwatts per square centimeter). However, the measured exposure dropped off by a factor of 10 within 2 inches of the maximum exposure site.

10. Balzano, Q., O. Garay, and F. R. Steele. "Energy deposition in biological tissue near portable radio transmittors at VHF and UHF," in record of the 27th annual conference IEEE Vehicle Technology Group, Orlando, Florida, 1977 as reported in NAS at 39.

11. BRH/FDA has now proposed performance standards for diathermy products 45 Fed Register 50359, 29 July 1980. It appears that the seriousness of diathermy device RFR exposure to operators is not as severe as originally believed. Due to poor "coupling," while the power density of the field appears high, not much RFR is actually absorbed.

12. General Accounting Office, of the United States, More Protection From Microwave Radiation Hazards Needed, HRD 79-7, (1978) at 17.

13. Testimony of Doctor Elliot S. Harris, Senate Report (95-49) at 587. The findings of the National Institute of Occupational

Safety and Health will appear in much greater detail when their "criteria document" on radio frequency and microwave radiation is issued. NIOSH hopes to issue the criteria document in draft in the near future. A criteria document is on extensive discussion of potential chemical or physical hazards. They are developed as a basis for occupational exposure standard setting by the Occupational Safety and Health and Administration for the Department of Labor.

As it is often the problem with references to research in the RFR area, the brief description of the findings does not discuss the equipment and methodolgy used in the field studies. This would appear critical here because worker exposure usually occurs in the complex near field of RFR sources.

14. Conversation with Fred Koomanoff, Chief Solar Power Satellite Project Office, Office of the Director of Energy Research, the Department of Energy, 9 August 1979. DOE and NASA have decided not to proceed with the next step in SPS development (Full Scale Engineering Development) at this time. Instead the program will be continued in a holding pattern until more research is conducted into generic research areas such as construction of large stuctures in space. Another factor in delaying the program is the slackening of electrical demand (conversation with DOE Solar Power Satellite Div, November 3, 1981).

15. Testimony of Doctor D. Phillips before certain subcommittees of the Committee on Science and Technology, US House of Representatives, April 13, 1978 as reported in committee print number 68 at page 132.

16. Id.

17. Department of Energy, "Preliminary Environmental Assessment for the Satellite Power System," DOE/ER-0021/2 (1978), volume II at 135.

18. Id. at pages 7-13.

19. Federal Communications Commission Notice of Inquiry, general docket number 79-144 at p. 16.

Chapter III

RESEARCH FINDINGS ABOUT BIOLOGICAL EFFECTS OF RFR

Scope of the problem

There are over five thousand reported articles and other documents involving biological effects of radio frequency radiation. The amount of literature is so great that there is even a publication devoted merely to updating the bibliography of the literature.[1]

In spite of all the research, the most consistent conclusion is that the research findings are still filled with contradictions and inconsistencies. But progress is being made. We are now coming to a better understanding of why some older experiments may have resulted in invalid findings, developing methods for making valid findings now and in future experiments, and most importantly are now starting to understand the biological mechanisms though which RF energy and the body interact.

Some of the problems associated with the ways that RFR acts and reacts when it strikes an object have already been discussed. Also discussed have been some of the problems with equipment used to measure radio frequency radiation in the environment at large and also, in the earlier days of research, measure effects of radio frequency radiation in the laboratory. A report of the Battelle Pacific Northwest Labortory commenting on early research in this area is particularly worth noting, because included as authors of the report is one of the leading researchers in biological effects of RFR: Arthur W. Guy of the University of Washington. Dr. Guy is also chairman of the ANSI C-95.4 subcommittee charged with reevaluating the ten miliwatt standard. Both Guy and lead author Don Justesen were members of the Ad Hoc working group for the Office of Science and Technology Policy and among those preparing the Technical Review of the Assembly of Life Sciences, section of the National Academy of Science Report on the Air Force's Pave Paws Radar. In the Battelle Report, they note:

> Emphasis was placed on data of more recent reports. During the past decade, marked strides have been made in the technology of measuring incident microwave fields (densitometry). Indeed, measurements of absorbed energy (dosimetry) were virtually alien to the microwave laboratory until the 1970s. Power density numbers reported in the literature prior to the 1970s are frankly suspect. Further, reports of experimental studies in which power densities were measured by accurate instruments and were validated by dosimetric techniques are quite recent, are relatively few in number, and are confined to the western literature.[2]

They go on to conclude regarding exposure systems and dosimetry in their report.

> Much of the experimental literature on biological effects of microwave radiation is based on poorly engineered exposure facilities, inadequate environmental control, poor dosimetry or no dosimetry, improper methodology, and instrumentation ill suited for collection of biological data during radiation. The problems that are borne of the manifold inadequacies of instrumentation, of dosimetry and of specification have contributed heavily to the public's misunderstanding of microwaves, to controversy among scientists and to the international disparity of microwave-exposure standards, which range by orders of magnitude. If investigators continue to limit their research to a quest for correlation between some biological effect and a power density, the goals for understanding and predicting biological effects of microwave radiation will never be realized.[3]

These comments in the Battelle Report underscore the central issue in developing effective, yet not overly broad regulations, in the RF Radiation area--we still don't have a complete understanding of how RFR effects humans and the environment. For an environmental regulation to be effective, it seemingly should be based on understanding how the substance being regulated affects health, safety and the environment, the forms in which the substance comes and any differences in enviromental consequences between these forms.

That some RF radiation must be allowed is a foregone conclusion. RF radiation in some quantity is generated by nature itself. There is an analogy to the RF radiation problem in water. Human beings need some water to survive, but if a human is immersed in water without an opportunity to breathe, drowning and death are inevitable. So, too, with RF radiation. So-called "Brain Waves" are minute patterned RF radiation fields apparently necessary for the brain to function. Yet, great amounts of RF can surely cause death or serious injury. The issue of regulating RF energy becomes not one of whether to permit RFR, but how much, and of what kind is it safe to permit.

To answer this question, we must turn to scientists to determine what kind and what amount of RFR is harmful. With RF energy this is a vexacious issue due to RF's unique physical properties as an energy form. And, as pointed out in the comments quoted from the Battelle Report, these unique physical properties make experimenting for environmental effects of RF very tricky.

The purpose of the remainder of this section is to provide an overview of some of the areas of scientific research on RF radiation bio-effects. The areas examined in the section were chosen either because they are areas of public controversy about RFR, or because, from a scientific standpoint, they appear to be an area of concern from an RF regulation standpoint. This material is merely intended to provide an overview. Substantial strides are being made every day to improve our understanding of RFR's bio-effects.

Thermal Versus Non-thermal Effects

A great deal of the controversy surrounding biological effects of microwaves and most of the dichotomy between eastern and western views regarding biological effects of RFR centers on the issue of thermal versus nonthermal effects.[4]

There is no question that sufficient amounts (power density) of RFR leads to a heating of human or animal tissue, which in turn can cause biological damage. Prior to 1953, it was believed that $100mW/cm^2$ was the lowest level at which significant biological damage would occur.[5]

Heating through RFR energy sufficient to overcome the thermo-regulatory mechanism of the body can lead to death as has been demonstrated in laboratory animals. Table 8 taken from Baranski and Czerski shows the thermal response of dogs, rabbits, and rats experimentally exposed to microwave radiation. Note that while a rabbit would die after thirty minutes of radiation, a dog of comparable size has only slight increase of temperature, primarily due to its superior thermo-regulatory mechanism. Baranski and Czerski generalize, that the lower the applied power density, the longer the time needed for attaining critical (fatal) temperature. They go on to state that at power density levels below 10 mw/cm^2, there is normally no increase in rectal body temperature beyond the ability of the thermo-regulatory system (of even a laboratory animal) to compensate for the RFR.[6]

Thermal effects are, therefore, often first noted in areas where the thermo-regulatory system of the body is least effective. One area of the body long known to be sensitive to RFR is the cornea of the eye--which has no circulatory system.

Justesen notes that a "thermal effect" in many respects is also dependent on the environment of the biological creature involved. He gives the example of a individual with severely compromised health, who already is suffering an elevated body temperature of approximately 106° Fahrenheit. If he were exposed to a field of as little as 1

mw/cm^2 at a frequency promoting maximum resonance he or she might expire within minutes. But Justesen also notes that a nude man in the Arctic tundra in a driving wind would probably quickly die unless he were subjected to some form of heating (perhaps as much as a 100 mW/cm^2).[7]

But a "thermal effect" may not be necessarily one based on "simple heating." Justesen notes the example of RFR "hearing" or auditory affect. This is the perception of a clicking or popping sound by a human subject whose head intercepts a pulse of microwave radiation. This phenomena appears to be caused by a "thermoelastic expansion" that takes place through an RF "pressure" wave which is believed to cause the click. While this "thermal effect" causes a pressure wave, there is no noticable rise in the temperature of the ear tissue absorbing the radiation.[8]

Baranski and Czerski note that it is important not only to examine the thermal effect in the context of the entire body but also to look at microwave thermal effects at the cellular and subcellular level. Important here is how different types of cells (e.g. lymphocytes and nerve or muscle cells) may react differently under RFR. This leads to the second category of effects, so-called non-thermal effects. These effects are postulated to be caused by changes in the electrical composition of cells or other ways in which cells react (e.g. the permeability of their membranes) not caused by a thermal, i.e. heating effect from RFR).

Figure 12 from Baranski and Czenski suggests ways RFR can interact with living systems to cause both thermal and non-thermal effects. Figure 13 is a table addressing possible interactions between RFR and a living system at various levels of organization (e.g. molecular, subcellular, cellular, organs and entire systems) and also what secondary events may arise from such interactions.

Biological Effects of RFR: Clinical Findings -- Cataract

The RFR-induced cataract is perhaps the best known adverse biological impact of non-ionizing radiation. In 1972, a disability award by the Board of Veterans Appeals to a Navy veteran for radar-related bilateral cataracts has been cited as the first radar-related disability award made in the United States.[9]

The prevailing American view is that cataracts are caused by thermal properties of RFR and can only be caused in humans at high power densities (greater than 100 mW/cm^2) with a duration of approximately 1 hour.[10] Most studies finding cataracts in exposures near 100 mW/cm^2 involved anesthesized animals. But, where heads of the awake monkeys

were exposed to a 3 cm wave length of radiation at 350 to 495 mW/cm^2, no cataracts were noted after repeated exposures and during follow-up observations over a period of two years. One report suggests that the difference may have been the cooling of the eyes by blood which flows into the monkey's head from the larger shielded portion of the body. This may have kept the eyes below the thermal threshold damage temperature.[11] Dodge and Glazer report a similar result in experiments using rabbits. Cataracts were caused in unshielded animals at power densities of between 25 and 50 mW/cm^2. But, where the entire body of the animal (except head) was shielded, the threshold for ocular damage was in the order of 300 mW/cm^2.[12]

But, there still are some inconsistencies. One review of RF effects notes a study where posterior surfaces of the lens were heated to similar temperatures at similar rates by both RFR and conducted heat. The RFR exposure resulted in cataracts, but lenses exposed to conductive heating did not result in cataracts.[13] Baranski and Czerski specifically leave open the possibility that the "microwave cataract" is not necessarily a thermal effect. But may result from a combination of heat and chemical change.[14]

Psychological Effects

One of the most controversial areas about RFR exposure has come in the area of behavior and possible effects to the central nervous system: both effects manifested by epidemioligical studies of behavior and those effects that have been found through clinical studies. Eastern studies have talked in terms of a microwave illness in their occupational safety and health literature for some time. They term this "the induction of a neurasthenic syndrome" in human beings who were exposed by working long periods of time in weak RFR fields. This syndrome is characterized by restlessness, insomnia, irritability, headache and impotence. This general RFR syndrome has yet to be noted in western studies.[15] The reason for this is unclear.

There have been numerous clinical findings of RFR effects on the central nervous system. These effects include both alterations of behavior and alterations in physiology. As in so much of the other research, early reports are followed by reports of poor instrumentation. Several early eastern studies were based on monitoring electroencyclephalograms. In these tests, electrodes are wired to the skull of the experimental subject and the brain wave patterns are recorded. A problem is that the sensors and their connecting wires may be "artifacts" creating possible hot spots which throw off power density readings. There is also a possibility that the connecting leads either disturb the pattern of the field, hence giving an invalid reading, or are influenced directly by the RFR field (i.e. by picking

up the transmitted RF rather than the brain's generated RF response) or both. But carefully structured western and eastern studies have reconfirmed several of the early findings.

Calcium Efflux

One set of experiments that apparently has documented an effect where there is no noticeable temperature rise are the calcium-efflux experiments of Drs. Adey and Bawin.[16] The original experiments were performed with the brains of sacrificed chicks and have now been duplicated, with similar results, in the brains of awake but paralyzed cats. These experiments are considered particularly significant due to the important role of calcium as the primary building block for the electrical properties of cells.

In the original experiments chicks were sacrificed and their brains dissected into two hemispheres. One was to be used in the experimental group, the other as a control. Each experiment consisted of 20 brain hemispheres, 10 experimental and 10 control. Both sets of hemispheres were soaked in a solution containing radioactive calcium (45 Ca^{++}). After triple rinsing with a non-radioactive solution the hemispheres were exposed or sham exposed for 20 minutes. Following the exposure or sham exposure, a sample of the bathing solution was measured for the amount of 45 Ca^{++} secreted by the brains using a scintillation counter.[17]

450-MHz RFR amplitude modulated at 16 Hz was used in the initial experiments. Exposures were at power densities of 50, 100, 500, 1,000, 2,000, and 5,000 uW/Cm^2. A statistically significant increase in 45 Ca^{++} efflux was found for those brains exposed to power densities from 100 to 1,000 uW/cm^2.[18]

The implication of the Adey-Bawin research, which has now been duplicated by one other researcher[19], is that there may be certain "windows" of power density and pulse characteristics at which RFR causes effects.

Electroencephalogram (EEG) Monitoring

There are many experiments which have shown changes in EEG patterns in situations where the experimental animal is being exposed to various levels of radio frequency radiation. For example, Adey and Bawin have been able to cause a burst in EEG waves by imposing/modulating RFR fields. So, too, can EEG bursts be trained as a conditioned response to a light or sound stimulus, but, in the presence of a RFR field, the rate of correct response to the light or sound stimulus substantially increased. The National Academy of Sciences suggests that such studies support the concept that "microwave fields modulated at EEG frequencies may

actually entrain neuro-electrical activities of brain structures that generate intrinsic electric rhythms at the same or closely-related frequencies."[20] The NAS goes on to note that it is important to distinguish between microwave fields which appear to influence brain tissue directly and fields strong enough to induce thermal stress. A thermal stress may cause endocrine change. In this latter case EEG patterns may shift as an element of the stress response and not a direct neuro-electric interaction. The concern about thermal effects comes from possible thermal stress at the point of contact of the EEG instrumentation and also the phenomena of resonance in the head.[21] Some western specialists believe that reported neural (behavior) effects are consistent with a thermal effect.[22]

Another problem, according to Dodge and Glazer, comes from extrapolating from animal findings to the human condition. They suggest that little is known about the thermodynamics of human tissues and even less about animal tissues. They believe it possible that humans and animals can act quite differently to subtle thermal changes. They believe such changes would be very dependent on individual tissue sensitivity or responsiveness to factors such as RFR. "There is possibly a great deal of variation in tissue sensitivity from species to species and even from organism to organism," they state. Superimposed on these knowns are the added unknown factors of such conditioned, tactile, auditory, and visual stimuli combined with radio frequency and microwave electromagnetic influences.[23]

Further confusing this area have been a number of relatively recent experiments monitoring EEG patterns which have found no significant differences between radiated and non-radiated groups. In one 1978 experiment (in which carbon electrodes where used to avoid problems associated with metal electrodes as artifacts), three groups of six rabbits each (three males and three females) where used in the test. Two groups were exposed to radiation of 2450 MHz at a average density of 1.5 mW/cm^2, two hours per day for three months. One group received continuous wave radiation and the other pulsed radiation; the third group was sham exposed. After three months, the researchers found no significant differences with regard to the EEG readings between the three groups.[24]

Another 1978 experiment used pregnant monkeys. From the begining of the second trimester of pregnancy, 33 of the monkeys were exposed three hours a day to 2450 MHz pulsed radiation to arrive at whole body specific absorption rates equal to those resulting from an equivalent exposure of .1, 1, and 10 mW/cm^2. These were then compared with a group of eight pregnant monkeys which were only sham exposed. Eighteen of the exposed mothers were continued to be exposed with their offspring for an additional six

months after giving birth, with the offspring being exposed alone for another six months after weaning. The researchers noted no statistically significant differences between the resting EEGs and photically driven EEGs between the exposed and non-exposed adults and/or their children.[25] In this experiment chronically attached (or in-dwelling) electrodes were not used. (This further reduced a potential artifact problem).[26]

Behavioral Responses

A very large number of eastern and a increasing number of western studies of RFR have involved behavioral experiments. For the most part these have been the classic type of experiments comparing behavioral reactions between exposed and unexposed test subjects. One problem with these experiments has been the use of pulsed microwave radiators which inadvertently introduce an auditory clue (such as an arcing noise) produced at the onset of the RFR pulses.[27] The types of behavioral responses can be categorized into two types: avoidance and work stoppage.

Avoidance

A number of studies have dealt with whether experimental animals when given the opportunity will avoid an area were there is an RFR field.

Two studies by Monahan and Henton indicate they will. In a 1978 study mice were exposed to continuous wave 2.45 GHz radiation (power level is not specified). The animals were free to move around and tended to place themselves so as to minimize the amount of energy absorbed. In a 1977 study, mice were exposed to a strong 2.45 GHz field (structured to arrive at a mean specific absorption rate of 46mW/g or approximately 51mW/cm^2). By interupting a light beam, the mice could turn off the RFR repeatedly for a 12-second period. The mice responded regularly by turning off the beam which was taken to constitute an escape or avoidance response.[28] The National Academy of Sciences questions whether animals can learn to escape from a continuous wave field but notes that animals will escape from a pulsed field. In one experiment by Frey and Field, albino were subjected to a pulsed field (130 to 300mW/cm^2 peak density, approximately .8uW/cm^2 average density. Rats were placed in a shuttle box, one half of which was shielded from the radiation. Frey and Field noted a preference for the shielded sided of the box. They also noted frequent re-entry by the animal into the field. In contrast, the rats were not reactive to a continuous wave field at a power density of 2.4mW/cm.[29]

In another recent (1978) western study, rats were exposed to 2,450 MHz continuous wave RFR for three months

at a rate of 500uW/cm^2. In observations during and after the three month period, the animals acquired an increase in avoidance habit; a difference in their sensitivity to electric shock was also noted. However, these changes subsided within a month after the exposure ceased. NAS opines that these differences are consistent with electrochemical changes of the body.[30] A (1977) eastern study dealt with the avoidance reaction at extremely low power density fields. Here rats were exposed to 2.375GHz radiation at 10 or 450 uW/cm^2, seven hours per day for 90 days. They were tested periodically for both learning and avoidance response, the extent of their open field exploratory activity, and their threshold for electric shock to the foot. In the beginning, avoidance learning was faster in the exposed animals, than the controlled, but at the end of the study this trend was reversed with the exposed animals then becoming slower than the controls. The foot shock threshold of the exposed animals was initially lower but became higher with the respect to the controls at the end of the study.[31]

Work Stoppage/Depression

Another number of studies have dealt with whether experimental animals will be less likely to perform a "preferred" task in an RFR field. In one group of experiments, a hungry albino rat was rewarded with food in a lever pressing task. The researchers noted that in otherwise standard environmental conditions, it would stop work with the ocurrence of RFR in a dose rate of 7 to 10mW/g. This corresponds to a density of approximately 10 mW/cm^2 in a field near the adult rats resonant frequency (900MHz) (Note: in a 2450MHz field, a power density closer to 25 to 50mW/cm^2 would be required to achieve that dose rate).

Eastern researchers found a weakening of conditioned reflexes in the animals as shown by increased latency or absence of response. This effect was intensified when inbred rats (having a more excitable CNS) were used. From this the researchers concluded the RFR acted directly on the CNS. In two experiments using pulsed radiation, a decrease of exploratory activity was noted both when rats were exposed to 2.45GMz for thirty minutes achieving an SAR of 6 to 11mW/g and also the radiation was 9.4GHz at 700uW/cm^2 for an unstated time. However, when rats were exposed to 3 or 10.7 GHz at power densities ranging from .1 to 25mW/cm^2 for times ranging from 185 to 408 hours, no changes in spontaneous motor activity were noted by the researchers.[32]

However, another study noticed an increase in locomotive activity and disturbance in response to operant behavior when rats were subjected continuously to a 2.45 GHz(2450MHz)

field so as to achieve a specific absorption rate 2.3 mW/g for 22 week period. The changes were detected almost immediately after the study started.[33]

Two reported studies involving primates as test subjects found no degradation of performance in a complex task situation under relatively strong RFR fields. In one experiment, two Rhesus monkeys were performing in a continuous tracking apparatus. They were exposed three hours a day for seven days to 3.2 GHz pulsed RFR with a power density of 80 mW/cm^2. No degradation of performance was noted as measured by deviation of the platform's horizontal position.[34]

A second primate experiment involved exposure to 1.2 GHz RFR at incident power densities of 10 and 20 mW/cm^2 in an arrangement designed to achieve a "worst case exposure" to allow maximum power deposition in the subject's brain. Again a complex tracking test was used requiring concerted attention by the subject of the experiment and finely tuned motor skills. Here the performance was motivated by shock as a stimulus rather than food reward. It was felt that the simple adverse stimulus was less likely to be affected by motivational heat stress factors than the food reward. During a total of 36 hours of RFR exposure, 720 checks were made to judge performance. Only 4 of those checks lay outside the data tolerance limits (which according to the researchers, were fewer than expected, by chance alone.) The test conditions have been extrapolated to a man-equivalent power density of 24 mW/cm^2 and 48 mW/cm^2.[35]

An Attempt to Resolve the Conflict

Cleary's 1977 monograph notes the increasing difficulty of explaining away inconsistency of results such as this now that our experimental methodology is better.[36] He goes on to essentially adopt the conclusions of Justesen that one important factor in reconciling these experiments is to look at the behavioral responses they are designed to test. He notes that many tests are designed to probe significantly different types of mental functions, (e.g. the powers of visual discrimination of a highly-trained primate as opposed to relatively simple forms of locomotive behavior in rats). Justesen notes that one way to explain the apparent sensitivity of rats is in terms of a thermogenic reaction which results in temperature elevation of 1 degree C or more. Justesen concludes that when the rise in body temperature, whether it comes from outside or inside the organism, results in an increase in the temperature of nervous material, this causes a probable increase in the rate at which volleys of neural impulses proceed. Therefore, according to Justesen, "the outcome could either be an acceleration of the clocking mechanism in the central nervous system or simple interference

because something funny is happening that distracts the animal from performing his task."[37]

Cleary then concludes:

> the results of recent studies of the effects of microwave radiation on the mammalian CNS, as manifested by changes in nerve structure, electrophysiology, or behavior, may be summarized by stating that low intensity fields appear, in some instances, to induce detectable changes. The response of the CNS to microwave irradiation is very much dependent on the biological endpoint investigated, illustrating the varied sensitivity of different nervous structures to such exposure. The limited number of endpoints investigated to date precludes a clear indication of which structures are most sensitive to microwave exposure. Consequently, there are no basic mechanisms to explain the effects of low intensity fields on nervous structures. Based on the majority of the data in this area, there is a strong indication that the microwave intensities that result in detectable changes involve tissue heating to a certain, albeit small, extent. The general lack of understanding of the relationship between low level thermal effects on the mammalian nervous system and the physiological or physchological responses make it difficult to determine the true extent to which microwave and RF effects are due to thermal perturbations.[38]

Cumulative Effects

Baranski and Czerski believe that there may be a possible cumulative effect of low doses of RFR radiation. They cite a study in which rats were subjected to irradiation waves changing from 300 to 920 MHz and back at a power density of 760u mW/cm^2, 24 hours a day (excepting examination periods) for 47 days. In comparison with controlled animals, researchers noted motor excitation from the beginning up until the 15th day. From that point on, there was a decrease in activity beginning on the 21st day becoming more pronounced between the 30th and 40th day. The animals became more emotive and their learning facilities decreased as evidenced by a water maze where the experimental group took longer and made more errors. The weight of the adrenals of the experimental group was reportedly significantly decreased in comparision with the control group. Gross weight and water intake were not influenced. Exposure to 500 uW/cm^2 for 40 days caused, however, only a decrease in motor activity.

Further experiments used low power density (.43 to .15 mW/cm^2 (430/150 uW/cm^2) in two frequency ranges (320

to 450 MHz and 772-900 MHz). It was found that the lower frequency exposures affected the activity more than those of higher frequencies.

Collectively, these experiments show that a certain duration of time is needed to observe the described effects.

The Eastern View

Baranski and Czerski, as representative of eastern authorities in this area, more readily conclude the existence of cumulative biological effects from low levels of radiation.

They acknowledge that it is premature to give an explanation to the mechanism by which RFR effects the central nervous system. They suggest, however, that it may come through a secondary interaction with peripheral nerves and receptors, direct interaction with various brain structures, or through local and general cardiovascular, endocrine reactions or temporary dependent or "non-thermal" metabolic changes which may in turn influence the CNS. They conclude with the possibility that the effects on the central nervous system may really represent symptoms of interference with other organs or stress imposed by the RFR on various regulatory and compensatory mechanisms of the body.[39]

Blood Brain Barrier

Another controversial aspect of the question of RFR health effects is the ability of RFR to interact with the "Blood Brain Barrier."

The barrier is a complex system that controls the interchange of wastes and nutrients between the blood supply and brain and prevents harmful ions and modules from entering brain tissue. In part, the barrier is formed by a continuous layer of endothelial cells lining cerebral capillaries. Electron microscopy has found "tight junctions" joining these cells which appear to lack the vesicles which would provide the means for transportation of molecules through the barrier. The make-up and functioning of the barrier is not completely understood. Several experiments, however, have indicated there is an apparent increase in permeability of the blood brain barrier when a test animal is in a pulse-modulated RFR field.

Earlier experiments had indicated the permeability of the blood brain barrier changed when the barrier was subjected to heating. One study subjected rat brains to $40^{\circ}C$ and found their integrity was destroyed after a heating of 45 minutes at that temperature. Fry exposed anesthetized rats both to pulsed and continuous wave of RFR at 1.2 GHz for 30 minutes. The pulsed RFR had average power densities of 200 uW/cm^2 with a pulse power density of 2,100 uW/cm^2.

The CW radiation had a power density of 2,400 uW/cm^2. Sham-exposed rats were used as controls. A substance emitting a florescence under UV light was injected into the test animals[41]. The animals were sacrificed, their brains sectioned and examined under UV light. Greater florescence was reported in the pulsed than in the CW RFR exposed brains with some control specimens also exhibiting slight florescence. This was taken to mean by the experimenters that the RFR had to some degree altered the blood brain barrier.

Another study by Oscar and Hawkins in 1977[42] involved rats exposed to 1.3 GHz for 20 minutes at various power densities. In these experiments a radioactive element was injected into the rats' carotid artery immediately after exposure. The animals were then quickly sacrificed; the amount of radioactivity taken into the brain was measured with a liquid scintillation counter. The researchers found statistically significant differences between radiated and non-irradiated animals at average power densities of less than 3,000 uW/cm^2 (3 mW/cm^2). They found that pulsed RFR was not necessarily more effective in causing permeability changes than continuous wave RFR. More importantly, in conditions of high pulse power density and large pulse widths (relatively few pulses per second) and under optimum conditions, the uptake of the radioactive substance could be effected in an average power density of only 30 uW/cm^2.

However, a later researcher[43] was unable to duplicate Oscar and Hawkins' results when he used 2,450 MHz RFR with power densities of 100, 500, 1,000 and 10,000 uW/cm^2.

There are also indications that RFR alterations in the blood brain barrier may be reversible.[44] The National Academy of Science's report suggested this may indicate changes in the tight junction integrity or pinocytotic transport rather than destruction of the cell membrane. It is currently known that the membrane may be reversibly opened by convulsive episodes, concussion, hypercapnia, acute hypertension and ionizing radiation.[45]

Neuroendocrinologic Effects

The neuroendocrinological system is made of a number of glandular structures which create chemicals which have various roles (primarily that of a message carrier) in the body.

One of the most important glands in the neuroendocrinological system is the hypothalamus. This gland can be looked upon in several ways including that of a "head-ganglion"[46] of the autonomic nervous system and as that primary source of nervous system input into the endocrines. The hypothalamus acts as a sensor of messages from the

thalmic, cortical structures and body fibers, including a number of those associated with the spine. The hypothalamus considers external and internal factors affecting the body's function and transmits that information in chemical messages to other parts of the endocrine system, acting as a master regulator.[47]

A number of studies have found changes in the endocrine system when a test object is being subjected to RFR. For the most part, these changes seem to be associated with a thermal response and elevated heating of the test object by the radiation.[48]

Studies so far have indicated that the endocrinological system response--general adaptation syndrome to RFR--is alarm reaction and exhaustion.[49] However, there is also some indication that the RFR-induced thermal stress response in the endocrine system differs quantitatively from the type of response normally found in the more usual forms of heating.[50] Most of the studies have involved higher levels of RFR (greater than 10 mW/CM^2).

Recent studies have indicated changes in levels of corticostrone, thyrotropine, and thyroxine (growth hormone). A 1977 study measured the release of thyroxine from the thyroid glands of dogs. During a local exposure of 2,450 MHz at 72 mW/cm^2, the rate of release over a two-hour period doubled. When the power density was increased to 236 mW/cm^2, the increased rate of release was 10 fold. During a lesser radiation, the temperature of the thyroid gland was 39°C; however, during the 236 mW radiation temperature level increased to 45 degrees Centigrade with the blood flow to the thyroid increasing by 70%. Another study of rats exposed to 2,450 MHz at 10 and 20 mW/cm^2 from 1 to 2 hours showed a steady level of thyroxine over 1 to 2 hours of exposure. A 1978 study exposed rats to 2,450 MHz radiation 8 hours a day for 7, 14 or 21 days at either 4 or 8 mW/cm^2 showed a decrease in thyroxine[51]. The researchers in this case observed the changes in the thyroid function were dependent on power density and the duration of exposure[52]. However, one eastern experiment reports a 4-hour treatment of 2,450 MHz RFR at 1 mW/cm^2 caused a transient increase in thyroxine in irradiated as opposed to sham-irradiated rats[53].

The primary indicant of activation of the hypothalamic/pituitary/adrenocortical (HPC) system in response to stress is an increase in corticosterone (CS). Recent studies confirm that CS production is strongly and positively related to increased body temperature, which in RFR terms is strongly related to the intensity of the field -- at least during short exposure conditions[54]. For example, rats exposed for 30 or 60 minutes at levels of 50 mW/cm^2 or more showed an increase in CS. When the rats are exposed

for 120 minutes at 20 mW/cm^2, there was also an increase.[55] In another study, exposure at 2,450 MHz for 24 hours at a non-specified power density found that the increased level was a transient condition lasting only minutes[56].

The NAS suggests that because the CS content is an index of the severity of stress as well as progression of the general adaptation syndrome, it is possible to interpret these conflicting results to say that radiation in a field on the order of 20 mW/cm^2 has provoked an alarm reaction but that the stage of resistance develops quickly[57].

Other studies have found a decrease (albeit with some conflict) in production of growth hormone (GH) while under RFR irradiation. In one study a 30 to 60 minute exposure at 50 mW/cm^2 led to a decrease in GH and a 120 minute exposure at 13 mW/cm^2 also found a GH decrease.[58]

RFR Effects Related to Blood

Another active area of investigation in the biological effects of RFR -- particularly by Eastern block researchers --are effects on the blood and blood-producing mechanism. Some research reports indicate that RFR fields inhibit the production of red cells while accelerating the production of certain types of white cells. Other effects from RFR exposure in the range of 5 to 30 m W/cm^2 include altered levels of glucose, blood urea-nitrogen ureic acid, serum enzymes, albumin and gamma globulins and free fatty acids. These appear to be transient changes in blood chemistry with a return to normal levels within one to two weeks after exposures to the RFR[59].

One of the more interesting effects that has been reported is a change in circadian rhythm of bone marrow mitosis (cell division)[60]. In one experiment, guinea pigs were exposed 4 hours a day for 2 weeks to 2,950 MHz pulsed microwaves in a power density of 1 mW/cm^2. These daily exposures were started either at 8 am or 8 pm to permit study of possible alterations in the cyclical rhythm of bone marrow mitoses. Phase shifts were noted in the pull of stem cells[61]. Experiments were later replicated at even lower power densities using mice. In yet another study using rabbits with exposure to 2950 MHz both pulsed and continuous wave RFR at a power density of 3 mW/cm^2 resulted in impairment of red cell production. Another observer had noted a phase shift in the circadian rhythm of blood temperature in rats which were exposed to fields of 1 mW/cm^2 for 1 to 8 hours. At least two of the current reviews[62] suggest these RFR effects upon the "biological clock" are reminiscent of the work of a researcher[63] who claims that man-made electromagnetic radiation could interfere

with the "natural" fields of solar and terrestrial origin which, he postulates, regulate circadian biological rhythms.

Findings as to the extent to which RFR fields cause increases in production of certain types of white cells are somewhat in conflict.

One eastern researcher[64] irradiated rats one hour per day for 216 days at power densities of 10, 40 or 100 mW/cm^2. He found that power densities greater or equal to 40 mW/cm^2 resulted in evidence of lymphocytosis and lymphopenia[65]. Similarly, an increase in lymphocites was also noted in another experiment which exposed large numbers of guinea pigs and rabbits to 10 centimeter radiation at power levels between 3.5 and 7 m W/cm^2 3 hours per day from 2 weeks to 4 months in both continuous and pulse wave forms. This researcher suggested that RFR led to a stimulation of the lymphoid system which is more pronounced with pulsed than with CW radiation.[66]

Another researcher, however, detected an increase in leukocyte, lymphocyte and neutrafile counts after only a 7 hour exposure of rats to 2400 MHz at 20 mW/cm^2. But this researcher also noted that blood cell parameters returned to normal within 7 days at exposure.[67] Still other researchers have found no change in blood composition following RFR radiation[68].

Cancer

Reports on potential biological affects of RFR in the popular press frequently connect RFR to cancer. Yet, that connection has not been clearly drawn in clinical studies.

The series of articles in the "New York Magazine" by Paul Brodeur (leading to a book entitled The Zapping of America) became the landmark popular "expose" of the ills of RFR radiation. Brodeur concludes the "cancer connection" ability of RFR was behind the Soviet's irradiation of the Moscow Embassy.[69] Brodeur also contends electromagnetic radiation is responsible for the increase of cancer in TACAN[70] maintenance workers, as well as the increased cancer rate in employees of the United States Embassy in Moscow.[71]

A more recent story "The Invisible Threat"[72] in a popular magazine notes that since the publishing of the Brodeur book, a third US Embassador in Moscow has also contracted cancer. The story goes on to suggest that microwaves may also be responsible for abnormally high cancer rate in New Jersey.[73] This article is principally aimed at potential ill effects from very low frequency RF radiation, such of those near powerlines. It goes on to quote a recent article in the Journal of Epidemiology noting that a study

of children with cancer in a residential area showed the greatest concentrations of afflicted children were found nearest to power line substations and, thusly, were exposed to ELF electric fields".[74]

In the technical literature, however, links from RFR to cancer are not apparent. In 1978, a technical report published by the National Institute of Occupational Safety and Health reviewed evidence in the literature of potential carciogenic effects of RFR. It found only two papers which made direct reference to an RFR carcinogenic effect. The first was in a paper allegedly documenting greatly increased incidence of cancer in a district of Finland which borders a region of the USSR which has a powerful missile warning radar installation. This report, however, has been criticized for being insufficiently documented.

The second paper[77] found a potential increase in the leukemia rate of mice exposed chronologically to RFR. However, it appears the report found only an increase in "leukosis," the count of white blood cells. There is no evidence in the report to confirm more complete examination documenting a diagnosis of leukemia. Though the leukosis condition is associated with leukemia, it also occurs in the presence of infections or abcesses. The NIOSH document concludes "at present the evidence linking RF/MW (radio frequency/microwave) radiation to carcinogenesis is speculative and circumstantial."

Because of concern over the Soviet irradiation of the Moscow Embassy, the State Department commissioned the Department of Epidemiology of the School of Hygiene and Public Health at Johns Hopkins University for a study on the health status of foreign service and other employees at the Embassy.[79]

The study, though self-admittedly not without fault,[80] concludes that there is no evidence that the Moscow group experienced any higher total mortality for any specific cause of death. The study compared both men and women assigned to the US Embassy in Moscow and those assigned to other Eastern European State Department assignments and the US population in general. In evaluating male mortality rates for example, the study states:

> Moreover, no differences were observed between the Moscow and the comparison groups either in total mortality or mortality from cancer--which was proportionately more frequent than the other causes of death in both groups, but still somewhat less in the Moscow group and somewhat higher in the comparison group than expected from the US mortality experience."

The study goes on to discuss mortality experience in female employees and notes a high proportion of cancer deaths. However, this held true both for those assigned to the Moscow Embassy and those assigned to other Eastern European groups (8 out of 11 and 14 out of 31, respectively).

The study goes on to state "however, it was not possible to find any satisfactory explanation for this, due mainly to the small numbers of deaths involved and the absence of information of many epidemiological characteristics that influence the occurrance of various types of malignant neoplasms." The study concludes with regard to mortality: "It should be noted, however, that the population studied was relatively young, and it is too early to have been able to detect long term mortality effects except for those who have served in the earliest period of the study."[81]

Birth Defects and Growth Abnormalities

Connections between RFR radiation and birth defects or abnormalities have also been among the allegations involving RFR health effects. But as with cancer, recent technical evaluations have not established any such link. One of the earliest reports connecting RFR to birth defects occurred in 1971. A group of scientists lead by the chairman of the Department of Public Health and Epidemiology at the University of Alabama studied congenital malformation on a county by county basis in that state. Further study indicated to them a very high proportion of children born with a congenital club foot at the hospital at Fort Rucker, Alabama. The prime mission at Fort Rucker was the training Army helicopter pilots. There are some 46 radar installations on various locations at Fort Rucker. Brodeur in his book <u>The Zapping of America</u> devotes a chapter to the findings at Fort Rucker and the follow-on events.[82]

The discussion of potential RFR-induced birth defects could be broken into two categories. 1) the mutagenic effect of those affected directly related to chromosomal abnormalities; and, 2) teratogenic or developmental abnormalities. Teratogenesis involves those abnormalities induced while the fetus is being carried in the womb.

Mutagenic Effects

There is no clinical evidence to support a non-thermal RFR mutagenic effect. What effects have been reported seem consistent with the effects produced not directly caused by radiation but by incidental effects such as heating.[83] Included in these experiments are a number involving bacteria. Bacteria experiments are helpful as a rough test to discover a potential for genetic effects because the bacteria multiplies so rapidly.[84] Baranski and Czerski sum up thusly: "It remains only to add that no satisfactory evidence of microwave

induced genetic effects or fetal damage in mammals was presented."[85] However, the fact remains that there have never been long-term studies of potential mutagenic effects of RFR.

Teratogenesis and Developmental Effects

There have been numerous studies finding teratogenic effects of RFR or other effects on early development.

Again it seems clear that if levels of RFR are sufficiently high so as to cause substantial heating effect (e.g. 1 or more degrees centigrade increase in the temperature of the organism), a teratological effect is likely[86].

But even though the incidences of abnormalities appears to be related to a "thermal effect," this is not to say that the abnormalities are caused by heat alone. In a number of experiments, a similar heat rise has been induced into a control group of specimens. In those cases where the heating was not caused by microwaves, the percentage of mortalities and abnormalities in the specimens is significantly less. This has lead some researchers to conclude that the effects may be caused directly by some facet of the RFR field other than mere heat.[88]

Of interest here is a group of 10,000 human fetuses which have been exposed to RFR while in the womb. For several years Jose Daels, a Belgian obstetrician, has used 2450 MHz CW radiation as an analgesic agent to relieve painful uterine contractions during labor. Daels reports the benefits have been a reduced time in labor and a reduced maternal demand for other forms of analgesic (e.g. narcotics). Power densities for the exposures have not been reported but are estimated to exceed 100 mW/cm^2 at the maternal abdomen, as fetal temperature typically rises 1 degree C after the period of exposure. Daels reports he has never found a harmful effect from RFR in the children exposed to the radiation.[89]

FOOTNOTES

1. Draft of the National Institute of Occupational Safety and Health Criteria Document and the Quarterly Review of RFR Bioefects Literature published by the Franklin Institute of Philadelphia.

2. Justasen, et al, Battelle Memorial Institute, Pacific Northwest Laboratory "Compilation and Assessment of Microwave Bioeffects (1978) at 3 (hereinafter SPS).

3. Id. at 37.

4. Glaser, Z. R. and Dodge, C.H., "Biomedical Aspects of Radio Frequency and Microwave Radiation; a Review of Selected Soviet, Eastern European and Western References in Biological Effects of Electromagnetic Waves, US HEW, (1976), at 3 (hereinafter Biomedical Aspects).

5. Id. Even at this level, approximately 30 minutes of continuous exposure was required to cause bilogical damages, conversation with John Mitchell, October 23, 1981.

6. Baranski and Czerski at 83.

7. Justesen, D.R. "Diathermy vs. Microwaves, Hearings on Radiation Health and Safety before the Committee on Commerce, Science and Transportation, United States Senate, June 16 to 29, 1977 (hereinafter Radiation hearings) at 228.

8. Id. at 228

9. Dula, A.: "Microwave Radiation" Jurimetrics Journal, (1978), American Bar Association at 297.

10. NAS, supra, at 68; Technical Review at 23; Battelle supra at 10.

11. Battelle, supra, at 10.

12. Biomedical Aspects, supra, at 14. (The 25-50mW/cm^2 appears at odds with most other reports indicating the need for Threshold RF levels of approximately 100mW/cm^2. Dodge and Glaser did not specify the period of irradiation however.)

13. Technical Review at 24.

14. Baranski and Czerski pp. 146-148.

15. SPS, supra, at 28.

16. Final Environmental Impact Statement, Pave Paws Radar System at Beale AFB, California, SRI International/United States Air Force (USAF), (1980) at C-45; Hereinafter Pave Paw S EIS at 61; Draft Supplemental Environmental Impact

Statement, Over The Horizon Back Scatter (OTHB) Radar in Maine, SRI, USAF 1981 at C-62. "Frequency and Power Windowing in Tissue Interactions with work Electromagnetic Fields," Proceedings IEEE Vol 68, No. 1 (1980) at 119.

17. Id.

18. Id.

19. Id. at 57.

20. Id.

21. Id. Note that because of their size, monkey heads may be particular susceptible to 2450 MHz radiation.

22. Biomedical Aspects at 13.

23. Id.

24. 10 microseconds, 100 pps, 1,500,000 u/cm^2/ppd.

25. Pave Paws EIS, supra, at C-53.

26. Id.

27. Pave Paws EIS, supra, at C-54.

28. Id.

29. NAS, supra, at 63, SPS at 26.

30. NAS, supra, at 63.

31. Pave Paws EIS, supra, at C-55.

32. Id.

33. Pave Paws, supra, at C-56.

34. There appears to be an exposure window; that is, a central range of frequencies, in which the effect is most likely to appear. But above or below these frequencies, the effect does not occur. "Biological Judgements in support of the Pave Paws Radar System."

35. Id USAF/SAM (undated) at 62 at 64.

36. Cleary, S.F., "Biological Effects of Microwave and Radiofrequency Radiation" in CRC Critical Review of Environmental Control, June 1977 (hereinafter Cleary) at 149.

37. Cleary, _supra_, at 150.

38. _Id_.

39. Baranski and Czerski, _supra_, at 117.

40. _Technical Review_, _supra_, at page 55.

41. Sodium Fluorescein.

42. Pave Paws EIS, _supra_, at C-49.

43. Pave Paws EIS, _supra_, at C-50.

44. NAS, _supra_, at 58.

45. _Id_.

46. Ganglion refers to a mass of nerve tissue outside the brain.

47. NAS, _supra_, at 64.

48. NAS, _supra_, at 64, Technical Review at 28, Pave Paws EIS at C-59.

49. _Id_., NAS, _supra_, at 21.

50. Technical Review, _supra_, at 29.

51. Also decreases in TSH and albumin but increases in Alpha Gobulin and Thyroxne binding

52. Pave Paws EIS, _supra_, at C-58.

53. NAS, _supra_, at 65.

54. Less than 2 hours, NAS, _supra_, at 64.

55. 2,450 MHz Pave Paws EIS, _supra_, C-58.

56. _Id_.

57. NAS, _supra_, at 64.

58. _Id_ at 65; Pave Paws EIS, _supra_, at C-58.

59. _Technical Review_, _supra_, at 30.

60. Important in blood formation. Battelle; _supra_ at 18.

61. Stem cells are cells in their most primative form which go on to develop to perform a specific function.

62. Battelle and NAS, supra.

63. Weaver (1974). See, SPS, supra, at 20.

64. Baranski and Czerski, supra, at 137

65. Id.

66. Battelle, supra, citing to Baranski at 18.

67. Deichman as reported in Cleary, supra, at 189 and NAS, supra, at 65.

68. Biological Judgments, supra, citing Lynn at page 17, Spalding at 16, Myers at 18. For further information on blood effects, see Cleary, supra, at 129 et seq. and Baranski and Czerski, supra, at page 137 et seq.

69. Brodeur, P. the Zapping of America Norton, New York, 1977 (hereinafter Brodeur) at 291.

70. TACAN is a system of RFR emitters used for air navigation.

71. Brodeur, supra, 126 to 131.

72. Schiefelbeim, "The Invisible Threat" Saturday Review of Literature, September 15, 1979, at page 16 et seq.

73. The Saturday Review Article suggests the connection thusly:

> "The link between cancer and microwaves has also been brought up in another recent development. Last year, the chief epidemiologist for New Jersey discovered that the cancer rate in Rutherford was way above normal. Five children at the Pierrepont Elementary School had developed cancer; the odds against such a situation, one report stated, were 10 million to 1. According to the FCC, some 6,400 sources of microwaves are located within a 15-mile radius of the town. The school itself is situated on top of a hill, a good target for microwaves. The citizens of Rutherford wanted microwave measurements. First the state assigned Bell Laboratory to do the job, despite the fact that its parent company AT&T was involved in a suit regarding a man who died from what his doctor claims was exposure to microwaves. When Bell's equipment proved faulty, a public uproar ensued; the National Bureau of Standards remeasured microwaves in the area. A spokesman for that group has found what he calls field strengths that are high enough to imply something. The data that we've got

will make other government agencies want to look at Rutherford, too.

74. _Id_. at 18.

75. Dwyer, National Institute for Occupational Safety and Health (1977) reported at Pave Paws EIS, _supra_, C-67.

76. Pave Paws EIS, _supra_, at C-68.

77. Provsnitz, 1962 at Pave Paws EIS, _supra_, C-68.

78. Pave Paws EIS, _supra_, at C-68.

79. "Foreign Service Health Status Study: Evaluation of Health Status of Foreign Service and other Employees from Selected Eastern European Posts," Department at Epidemiology, School of Hygiene and Public Health, the Johns Hopkins University, July 31, 1978 (hereinafter Foreign Service Study.)

80. _Id_. at section 8 page 234.

81. _Id_. at page 243.

82. Brodeur, _supra_, chapter 11 "The Cancer Connection."

83. Pave Paws EIS, _supra_, at C-37; Technical Review, _supra_, at 31.

84. Scientific American, August, 1978; Technical Review, _supra_, at 31.

85. Baranski and Czerski, _supra_, at 134.

86. Pave Paws EIS, _supra_, at C-35 _et seq_.

87. Cleary, _supra_, at 142, NAS at 67.

88. _Id_.

89. Battelle, _supra_, at 14.

EPIDEMIOLOGICAL STUDIES

Most of the evidence discussed so far, as to the effects of RFR on biological entities, has been evidence developed in laboratories. Almost invariably this evidence has involved controlled laboratory conditions in exposure of laboratory animals or samples of biological media (e.g. bacteria cells). But as we have discussed, the characteristics of RFR exposure change in relation to the physical characteristics of the area being exposed and also to the nature of the RFR fields. This is easy to understand considering factors like continuation (i.e. the loss of power by an electric field as it moves through biological matter), and extrapolition of data from the radiation of a small laboratory animal at a given power density to estimated results when the same power density and frequency are applied to a human being.

For the most part, the extent of information of RFR biological effects hazards on human beings to date has involved epidemiological studies. In general these studies involved comparing various criteria (such as various indicia of health status: headache, psychological effects, blood characteristics, cancer) and the incidence a population that has been exposed to RFR has been affected as opposed to a population that has not been similarly exposed. For the most part, these studies have involved populations which "clearly" have been exposed to RFR. These populations include radar and microwave workers and persons who held certain jobs in the military. There appears to be no study that attempts to trace the health status of the general population which has been exposed to low levels of RFR against those who have not. The prime problem here is that with the great increase in RFR use, it would be hard, if not impossible, to find a completely unexposed group. Further, if one could find such a group, it would be so different from the experimental group in so many facets of its existence (diet, standard of living, etc.) that it would be hard to attribute any potential effect to RFR exposure as opposed to some other factor.

Epidemiological studies are one area where there appears to be a fairly straight forward split of opinion between eastern and western researchers. Eastern researchers cite several studies as documenting various forms of health-related effects from RFR exposure. Western researchers, on the other hand, have done very few studies which essentially have been inconclusive.

Western Studies

Two recent western studies are of note, first, because of their size and, second, because of the inconclusiveness of their results.

The first was the study of employees of the Moscow Embassy[1], alluded to in Chapter II. By its own admission, there are problems with the study. Most of the information as to health status was gained by follow-up questionnaires. Also, it is almost impossible to clearly document the level of exposure of various persons at the Embassy. Some results, however, are interesting. One is the higher rate of death due to cancer among females employed at the Embassy as opposed to females employed at other Eastern European posts.[2] Also interesting are the complaints of depression, irritability, difficulty in concentrating, and memory loss that came through in the studies. These parallel the findings of Soviet researchers. However, the persons in the Moscow Embassy group registering the greater incidence of these complaints worked at places inside the Embassy receiving the lowest exposure to microwaves as compared to others in the study group.[3]

Two epidemiological studies received extended treatment in Brodeur's book.[4] One is a mid-1960's study published in the bulletin of the Johns Hopkins Hospital. Initially this study found a link between children with mongolism (Down's syndrome) and parental exposure to RFR. The second study involved an apparent connection between exposed fathers and a higher rate of club foot birth deformity in their offspring.

The first study (sometimes called the "Baltimore" study) involves a review of data records at Baltimore Hospital and interviews with patients. The researchers there found a statistically signficant connection between paternal radar exposure and mongolism.[5]

A follow-on study was conducted (this time with more detail as to paternal exposure to radar). While the newer study continues to find a positive correlation between paternal military service and the incidence of mongolism, that correlation appears less than indicated in the first study. However, the original findings as to paternal exposure to radar and the incidence of mongolism were reversed.

In the 1965 study, there were three categories of exposure: 1) fathers definitely exposed to RFR; 2) those fathers probably exposed to RFR, and 3) the control (or non-exposed) group. In the original study, children afflicted with mongolism were born to 18.6% of the definitely exposed fathers as opposed to 15.2% for the control or non-exposed group. In the 1977 study, the incidence of the mongolism birth defect was 17.4% for definitely exposed fathers as opposed 17.5% for the control group. When the exposed or probably exposed category of fathers was included the numbers became 22.7% verses 20.6%.[6] This new data has caused the authors of the study to retract from their view that

radar association can positively be connected to the incidence of the mongolism birth defect.

The 1971 study compared incidences of congenital defects in 67 Alambama counties during the period from July 1969 to November 1970. The state-wide average was used to compute the expected number of anomalies. In certain categories six counties departed significantly from the random distribution of defects. Among these counties were Coffee and Dale counties, located near the Army's Fort Rucker. Fort Rucker is a primary training facility for helicopter crews. The installation is spotted with many radar facilities. The training program includes numerous practice runs by helicopter students coming toward radar installations and landing their craft. One physical characteristic of a helicopter is that the front of the craft is made up largely of plexiglass, which compared to metal, does not attenuate the strength of RFR. Brodeur suggests that these pilots and copilots in their repetitive landing exercises received the full force of RFR radiation to their genital areas as it passed through the plexiglass.

Two follow-on studies were conducted, one in 1973 which broadened the study into birth defects and fetal death rates, not only for Alabama but also Eglin AFB in the Florida panhandle. Again, the Fort Rucker Hospital (Lyster Army Hospital) was found to have an abnormally high rate of birth defects and fetal deaths. Eglin AFB Hospital reported nearly the same fetal death rate as that at Lyster.[9] Another study was conducted.[10] There were some changes made in the survey technique, including sending questionnaires to 46 Alabama hospitals to get more detailed information on hospital characteristics in reporting procedures. In this study, they found that the highest reports of birth defects in hospitals were both from Fort Rucker and the hospital at Maxwell AFB. However, they also found that 13 of the 17 Alabama counties with the highest anomaly rates were in a continuous band across the state. More specifically, they found that the rate of anomalies for Coffee and Dale counties, placed them as only the sixth and eighth highest counties respectively, among 67 Alabama counties. Five other Alabama hospitals also reported incidences of anomalies not significantly lower than those reported at Lyster hospital. This and other information lead to a conclusion that the connection between RFR exposure of helicopter students at Fort Rucker is not causally-connected to birth defects.[11] As summarized in the OSTP's "Technical Review", "The incidences of congenital anomalies in children of helicopter student pilots was evaluated by examining birth records to investigate possible association with paternal radar exposure. It was concluded that there was no significant excess in congenital anomalies attributable to microwave exposure."[12]

Two other western epidemiological studies deserve note. In a five-year research project, Army researchers reviewed some 1,500 military members working with microwave equipment for various forms of ocular abnormalities, including opacities (cateracts), vanoculars, or posterier subcapsular iridescence. They found no differences in ocular condition between the microwave workers and unexposed persons of comparable ages.[13]

Perhaps the most ambitious western epidemiological study has been one involving the review of forty thousand former Navy servicemen during the period from 1955 to 1976.[14] This study by Robinette and Silverman was not able to quantify the exact exposure data for the persons involved. Rather they separated the personnel into two groups of approximately twenty thousand each. One group was those assumed to have been subjected to RFR in their military duties. The second group was primarily operators of RFR equipment who were normally located at places where they would not be directly exposed.[15] This procedure has been criticized because of questions as to whether the so-called "unexposed group" of radar operators really qualifies as a "control" group.[16] While this study has no clearly unexposed group, the study does evaluate primarily shipmates. Therefore, other various environmental factors should be similiar between the two groups.

So far the only reports have involved differences in mortality between the two groups. The study breaks down both mortality in general and mortality contributed to various diseases (e.g. strokes, cardiovascular, pneumonia, and leukemia.) There appears to be no statistically significant difference between the two groups in total mortality attributable to RFR exposure. The exposed group did have a significantly higher death rate from trauma; but, this seems primarily attributable to the fact that many of those went on to become flyers and the trauma-associated death category involved military aircraft accidents.[17] On the whole, the death rates for both groups were lower than those for comparable age groups in the U.S. population at large.[18]

Eastern European Studies

While the western epidemiological studies have not clearly found RFR health effects, those conducted in Russia and Eastern Europe have. But again these studies have also be critized in the West.

Christopher Dodge of the Congressional Research Service has been probably the West's most active follower of Soviet and Eastern European RFR bioeffects literature. In 1969, he critized Soviet occupational research reports for their lack of specificity about irradiation protocols and details in environmental and other exposure conditions potentially

affecting the results of the survey.[19] Baranski and Czerski took exception to that critizism in their 1976 treatise as follows:

> It should be pointed out that Gordon...as well as other Soviet authors...analyze working conditions very carefully, taking such factors as air, temperature and humidity, noise and lighting into account. One factor that is usually omitted from these, as well as other, analysis is the problem of nonintended nonionizing radiation, in contradistinction to the ionizing radiation which is very carefully assessed.
>
> In view of this, it seems that the objections presented by Dodge...concerning the lack of pertinent data on the circumstances of irradiation and the possible influence of various other environmental factors in Soviet clinical papers are not altogether well founded. Attempts to present detailed data as to the source of microwave radiation, effective area of a radiation, position of the body in respect to the field, etc...for an individual worker for a period of several years would be misleading to an extreme degree. In the present authors' opinion it is far better to present approximate evaluations than to create impression of accuracy where none can be had.[20]

Nonetheless, Dodge and his coauthor in a 1977 article, reaffirmed their concern about the paucity of data as to other RFR fields which may be present and affecting the Soviet work place.[21] The report of the ADHOC Working Group of the Office of Science and Technology policy quotes a cautionary note in interpreting Soviet and Eastern studies thusly:

> The bulk of the published human data on RFR effects is from Eastern European sources. The interpretation of findings is difficult due to different methods of reporting and to different pathophysiological orientations in the West and Eastern Europe. Eastern European pathophysiology, with a Pavlovian tradition, is strongly function oriented. As a result of these philosophical differences, the interpretation of epidemiological data can differ widely between east and west.[22]

With these cautions in mind, the sheer weight of Soviet studies finding similiar effects in RFR workers is impressive. A table prepared by I.G. Ramzen-Yevdokimov and V.A. Sorokin in a 1970 monograph <u>Influence of Microwave Radiation on the Organism of Man and Animals</u> showed the following repetitive findings:

TABLE 8

AUTHOR	HEADACHE	INCREASED FATIGUE ABILITY	DISTURBED SLEEP	IRRITABILITY	DIZZINESS	SWEATING	FORGETFULLNESS	NUMBER OF EXAMINATIONS
N. V. Uspenskaya 1963	37	31	29	16	9	7	4	100
M. N. Sadchikova 1963	12-39	20-35	-	8-27	-	-	6-28	447*
Klimakova-Deutschova 1963	43	39	35	-	-	-	-	73
Sercletal 1959	43	4	45	10	-	-	-	103
Iranyi (1960) 73	50	40	60	-	10	39	-	
N. V. Tyagin 1966	33.5	46.2	25.3	9.6	-	25.5	-	573
Authors' Data	44	29	35	36	18	25	11	155

CONTROL GROUP

Uspenskaya 1963	15	22	2	10	6	-	2	100
Sadchikova 1963	8	10	-	8	-	-	-	100
Tyagin (1966)	10.8	5.9	8.7	-	-	2.7	-	184
Authors' Data	7	8	3	-	-	4	-	50

Table ___ Characteristics of complaints submitted by microwave generator personnel according to various authors (in percent of number of subjects).[23]

Baranski and Czerski report on a continuing research effort involving Polish microwave and radar workers.[24] This research effort groups the workers into three groupings: Those receiving the lowest exposure (averaging 10 to 100 or so uW/cm^2) are labeled the "E" group; those exposed to, on the average, 100's of uW/cm^2 are the "ES" group, and a group exposed to high power densities (Average 1 to 10 mW/cm^2) the R group. In the ES and R group, Baranski and Czerski state that the results confirm the findings of Soviet researchers as to the occurrence of subjective complaints. Those exposed to the lowest levels (E group) did not show any symptoms up to ten years of work with RFR emitters.[25] The higher the exposure levels, the more frequent the subjective complaints.[26] The highest group also experienced, after a period of time, changes in blood pressure, white blood cell count and a decrease in alphawaves.[27]

Similar results pertained in a study by Sadcikova published in 1974. There, two groups were involved, including one thousand persons who have been subjected to up to a few thousand microwatts/cm^2.[28] Again, increased symptoms of the "microwave syndrome" were found in the exposed groups as opposed to the control group. However, in nine of sixteen symptoms, incidences were higher than among those workers who had been exposed to a few tens of microwatts per centimeter square as opposed to the group which had been exposed to substantially higher power levels.

Klimkova/Dutschova surveyed 530 workers occupationally exposed to RFR. A control group was made up of miscellaneous administrative personnel. The subjects were further grouped by age and frequency of irradition. Several sorts of effects were noted. However, changes in brainwave patterns, blood sugar, protein and cholesterol levels were more pronounced for people exposed in the 3 to 30,000 MHz range.[29]

Pazderova surveyed 142 Czech radio and television technicians to study blood protein levels. Researchers found that while the levels were all within normal limits, there was a statistically significant difference in the mean levels of the exposed group as opposed to the control group.[30] However, there is one Polish study that appears at odds with most findings in the traditional Soviet/Eastern European occupational surveys. Siekierzynski and four researchers studied 507 Polish male radar station workers occupationally exposed to fields between 200 and 6,000 uW/cm^2 with another group of 334 at the same radar stations exposed to less than that amount of radiation. In both cases, the period of exposure ranged from 2 to 16 years. Researchers found no correlation as to the incidence of functional abnormalities such as headache, fatigue, emotional instability, concentration, sweating, etc. and to the power density or the duration of the exposure. They did, however,

find a positive correlation as to the incidence of functional disturbances and the age of the workers involved.[31]

The NAS in discussing epidemiological studies notes the following:

> The Eastern European literature (e.g., Gordon) consistently points out the difficulties of separating the reported biologic effects attributable to microwave exposure from the biologic effects that may result from other factors in the work environment, such as noise, ambient temperature, humidity, illumination, frequent separation from one's family, or isolation from large population centers when servicing or operating microwave equipment in remote areas. Distinguishing the effects of microwave radiation from those of other factors is more difficult when exposure to low power densities (1-5 mW/cm^2 or less) is involved. Even in the case of radar workers who are exposed to little or no microwave radiation, there are complaints about eye fatigue, headaches, bradycardia, hypotonia, and general fatigue. Gordon believed that such symptoms may be attributable to illumination that is less than optimal or to the need to stare at video terminals (cathode-ray-tube displays) for long periods. The difficulty of distinguishing signs and symptoms attributable to microwave exposure than those due to alcohol consumption, smoking, over work, or obesity must also be noted.
>
> Although most investigators have attempted to control experimental variables so that discernible differences in individual responses could be attributed exclusively to microwave radiation, there is still appreciable uncertainty in attempts to control such factors as motivation, personality characteristics, tolerance to assigned work tasks, personal problems, and anxiety. All these could have a major effect on the incidence of headaches, irritability, and restlessness in study participants.
>
> The Johns Hopkins finding of complaints of headache and irritability in U.S. Embassy employees and dependents were remarkably similiar to, if not identical with, the neurasthenic syndrome reported by Eastern European investigators, but the Embassy people were only occasionally exposed to microwave radiation and the exposures in general appreciatably below 5 uW/cm^2. Questions therefore remain as to the suitability (sic) of present methods for detecting subtle changes in groups

of people exposed (and unexposed) to microwave radiation at low power density. An associated difficulty is related to the failure of almost all the published epidemiological studies to specify the analytic limitations of their techniques.

. . .

The effects of long term exposure to microwave radiation at low power densities (e.g. less than 1 mW/cm^2) have not been adequately assessed. There is no evidence of a cumulative effect on humans, but the question is unresolved.[32]

Additional research is recommended to clarify further the possible effects of long-term exposure to microwave radiation at low power densities.

Future of Western Epidemiological Studies

A consistent recommendation in federal studies on the future course of RFR bioeffects research has been for some form of definitive epidemiological study.[33]

As discussed so far, the two major US epidemiological studies--the study of Naval personnel and the study of US Embassy personnel in Moscow--have been inconclusive. Two other studies are currently in progress. One is of male physical therapists, sponsored by the Bureau of Radiation and Health and the second is a National Institute or Occupational Safety and Health Study of workers using RF sealers. This later study is in the developmental stage.[34] The National Institute of Occupational Safety and Health is proposing to publish a criteria document which can be used as the basis of the Department of Labor standard under the Occupational Safety and Health Administration for workers exposed to RFR. The draft criteria document circulated in the late spring of 1979 proposed a comprehensive medical monitoring program for all persons exposed to RFR at the level in excess of $100 uW/CM^2$. This recommendation was evidently critized by persons commenting on the draft criteria document because of the cost of implementation.[35] It is not clear whether when the criteria document is ultimately issued will contain a similar monitoring requirement. Such a monitoring requirement, if required, could form the basis of a prospective[36] epidemiological study.

There are several problems with epidemiological studies of RFR bioeffects, particularly those evaluating lesser levels of exposure. As discussed in the section on clinical experiments, we still have no clear idea of what effects we may expect to find from various levels of RFR exposure and how these effects would outwardly manifest themselves

in the study population. Futher complicating an epidemiological study, particularly one evaluating a population as a whole as opposed to a more carefully controlled group of workers, is the need to have some degree of control over a shifting population. Also difficult is the need to assess competing environmental factors which may effect the outcome of the study and problems of reflection and refraction to accurately judge the exposure level. How to conduct a proper epidemiological study in the RFR area, due to problems of accurately comparing exposure and proper populations, was one of the most hotly contested issues at a recent meeting of the Electromagnetic Radiation Management Advisory Council.[37]

FOOTNOTES

1. Lilienfeld, A. et al, Foreign Service Health Status Study, Evaluation of Health Status of Foreign Service and Other Employees from Selected Eastern European posts, the Department of Epidemiology the school of Hygiene and Public Health, the Johns Hopkins University, July 31, 1978.

2. Cleary, S. F. et al, Analysis of the Exposure Levels of Potential Biologic Effects the Pave Paws Radar System, the Assembly of Life Sciences, National Academy of Sciences 1979 (hereinafter NAS) at 71.

3. NAS, supra. at 74.

4. Brodeur, supra. at 91-92 and 134 et seq.

5. Sigler, A. T.; Lilienfeld, A. M.; Cohen B. H. and Westlake, J. E. "Radiation Exposure in Parents of Childern with Mongolism (Down's Syndrome)" in the Bulletin of the John Hopkins Hospital, Volume 117, at 374-379 (1965).

6. Pave Paws, supra. at C-28; Technical Review, supra. at 21.

7. Brodeur, supra.

8. Id.

9. Pave Paws, supra. at C-29.

10. Id.

11. Id.

12. Technical Review, supra. at 22.

13. NAS, supra. at 73; Pave Paws, supra. at C-29.

14. Robinette, C. D. and Silverman, C. "Causes of Death Following Occupational Exposure to Microwave Radiation (Radar) 1950-174" in Hazzard, D. G. (Ed.), Symposium on Biological Effects in Measurement of Radio Frequency/Microwaves, the Department of Health, Education and Welfare, Washington D.C., HEWPUB. No. (FDA) 77-8026 (1977).

15. Pave Paws, supra. at C-28; NAS, supra. at 72.

16. NAS, supra. at 72.

17. Pave Paws, supra. at C-29.

18. Id.

19. Dodge, C. H. and Glaser, Z. R. "Trends in Nonionizing Electromagnetic Radiation Bioeffects Research and Related Occupational Health Aspects," Journal of Microwave Power Volume 12, No. 4 at 329 (1977).

20. Baranski and Czerski, supra. at 154.

21. Dodge and Glazer, supra. 1977, at 329.

22. Technical Review, supra. at 22.

23. Ramzen-Yevdokimov, I.G. and Sdrokin, V.A. Influence on Microwave Radiation on The Organisims of Man and Animals, (Petrov, I.R. Ed.) Meditsina Press, Leningrad; 1970 at 132 (NASATT F-708)

24. Id. at 160 et seq.

25. Id. at 162.

26. Id.

27. Id. and NAS, supra. at 70.

28. Pave Paws, supra. at C-33. Interesting here is that the USSR implemented their 10 microwatt occupational standard in 1958. Nonetheless, in this study, researchers were able to find 1,000 workers who had been subjected to RFR levels in their work place of up to 600 times that standard. To some western observers, this and other facets of the USSR's implementation of their RFR standard call into question whether it is really enforced.

29. Cleary, S.F., supra, at 133; PAVE PAWS at C-34.

30. In the Battelle study for the solar power system, this research effort is cited to the Journal of Microwave Power, Volume 11 at pp. 144-145 (1976); the PAVE PAWS, EIS for Beale AFB and the NAS report cite essentially the same study to Aerospace Medicine Volume 45 pp 1143-1148 (1974). This citation to Aerospace Medicine is interesting because Czerski is listed as a co-researcher. Further, this study is not cited in the Baranski and Czerski book, even though they were seemingly meticulous about going back and adding more recent data even during the proof reading stage (at 227).

31. Battelle, supra. at 9, PAVE PAWS, supra. at C-33, NAS, supra. at 70.

32. NAS, supra. at 77-78.

33. December 1971 ERMAC report at 22; Technical Review, supra. at 47.

34. NTIA task force proposal (second draft) November, 1979 at 76.

35. Conversation with Z. Glaser. November 1979.

36. A prospective epidemiological report is one in which the group being investigated under a control group is followed closely throughout the period of the experiment. The other form is the retrospect of epidemiological study which is an after-the-fact study and based solely on records. The preferred form of study is the prospective because of the ability to control factors in the study.

37. ERMAC Meeting, 16 July 1980, Washington, D.C.

Chapter V

STANDARDS

One of the more controversial aspects of concern about potential harmful effects of microwave radiation is the wide disparity between Western and Eastern (Soviet-bloc countries') safety standards.

Standards in this area can be separated into two basic categories: occupational standards (which tend to be based on shorter term exposure--such as that which might occur in the work place); and environmental standards--standards governing exposure of the general population on a day-in day out basis.

In the area of RFR standards, higher levels of exposure tend to be permitted for shorter periods of exposure. Conversely, only lesser radiation levels are considered "safe" if the exposure is going to be for a longer period of time.

Since, as a general proposition, regulation of electromagnetic radiation will have to be based on some form of defensible standard of exposure, this chapter will examine the primary world RFR safety standards, their basis, and two projects underway to revise the 10 milliwatt standard, the most widely accepted among western nations.

STANDARD SETTING PHILOSOPHIES

In order to better understand this discussion of world standards, A review of the philosophy of standard setting will be helpful. The fundamental question is: "how safe is safe?" This is not only a question of science, but more often is settled in the spheres of politics, economics, administration, philosophy, and law. A primer in the differing philosophies on this question between East and West will help us understand some of the basis for the difference between Eastern and Western standards.

The Western philosophy, because of its more public process for health standard setting is much easier to adduce. Simply, it's generally based at that level of exposure (sometimes called Threshhold Limit Value or TLV) at which there are no harmful effects from the substance being regulated.[1]

It is harder to know how the Eastern bloc nations set standards, however, the process in the Soviet Union appears typical.[2] Standards are set by a Council of Ministers. The meetings are closed with no minutes published. There are also no "criteria documents" published setting forth the basis of the regulations. Of course, the regulations are

not subject to challenge in open court proceedings. Though the Eastern nations lack the procedural amenities of U.S. standard setting, with some interesting exceptions, their philosophical basis for standard setting appears more conservative.

Based on statements by Eastern representatives; and comparing their standards to published data, it appears the Eastern nations set standards at that level which will not change the physiological condition of any one exposed. That is, the American, and to a large extent the Western philosophy asks only whether a level of exposure will cause a discernable "harmful" change: but Eastern nations only look to see whether there has been a change -- irrespective of whether it is known to be harmful.[3]

This raises two more issues. The first is a problem for both East and West: what happens if the "change" is difficult to perceive? Often it is, and this calls for building a margin of safety into the standard. How large that margin should be then becomes the next policy decision.

The tradition in the Western nations has been to use a factor of 10 as a margin of safety. Therefore, the standard will often be one tenth the amount of exposure at which a harmful effect is observed. But the Eastern nations will frequently use a factor of 100. Their limit then becomes one one-hundredth the exposure at which any physiological change is observed. Obviously this makes for a potentially much more conservative Eastern standard.

There are still other complications arising from the issue of Eastern and Western differences and how changes are observed. As discussed previously, Western research (and hence observation of harmful changes) is primarily based on clinical studies. Eastern nations, on the other hand, derive many of their research findings from their traditions focusing on Pavlovian type experiments and epidemiological studies.

One benefit to the Eastern orientation is that it is more likely to identify possible synergistic effects stemming in part from the substance being investigated; as the focus, of the research is not on comparing the one particular substance being investigated to the one particular type of effect. However, the limitation in Eastern studies stems from ensuring the effect during the research is actually being caused by substance (in this case RFR) under investigation and not by some other substance.

A second issue affects both Eastern and Western standard setting philosophies (But to a much greater degree those of the West). This issue involves treatment of potential long term irreversible effects from low level doses. Here the

question becomes "how long is long?" And, if the only way to test a substance for long term effects is with long term experimentation, what should be done in the interim? This then becomes an issue of how to "hedge our bets" during the interim against presently unsuspected long term effects.

The Eastern approach to standard setting is more conservative and appears more "comfortable" to those concerned about potential long term adverse effects. The Eastern focus of setting standards based on <u>any</u> observable change as opposed to only a known harmful change, helps preclude the possibility that some change not currently understood to be harmful will not prove in the future to be harmful. Also more cautious in this regard is the Eastern tendency to reduce exposure limits by a factor of 100 rather than 10.

But nothing comes without it's price. Particularly in an area like RFR, the use of which, by and large, is to the benefit of society at large: communications, medical therapy devices,information, national defense, public safety. The policy problem this raises can be highlighted through the following, analogy: Some people are deathly allergic to fish and fish products. But fish is an excellent source of nutrition and a staple for much of the world's population. The use of fish meal as a protein supplement helps provide the difference between life and death to large numbers of the world's starving. Should we ban fish as a foodstuff because it may be harmful to a few? The answer appears obvious. But the question becomes more difficult when the benefit-detriment ratio is not so clear, and where the scientific information falls woefully short of what is needed to make a clear choice. As noted at the outset, the question is not so much scientific and legal, but philosophical and political and outside the scope of this paper.

Current Standards

With the philosophical issues behind us (albeit still unresolved), let us review the current world standards.

U.S. Standards: The primary Western standard is based on average power densities and is an outgrowth of the American National Standards Institute (ANSI) radiation protection guide. It applies to RFR frequencies from 10 to 100,000 MHz (100 GHz). The basic standard, as discussed in preceeding chapters is 10 mW/cm^2 averaged over any six minute period. As RFR is comprised of both an electrical and a magnetic wave component, the standard can also be expressed in terms of those components:

The standard also is limited to an <u>average</u> exposure over a 6 minute period. That is a one minute exposure to 60

mW/cm^2 would also be allowable under the standard.[4]

This standard has been adopted by OSHA, as an occupational standard, but only holds the status of a non-binding guideline[5].

The only nation-wide, binding RFR standards are those which stem from the Radiation Control for Health and Safety Act of 1968.[6] Under that act, the Food and Drug Administration through the Bureau of Radiological Health is authorized to issue performance standards governing the emission of ionizing and nonionizing electromagnetic radiation and sound waves from "electronic products"

At this time, microwave ovens are the only category of RFR emitting products regulated under the Act[7] -- however, a standard for diathermy devices has also been proposed.[8]

The microwave oven standard involves a relatively complex testing regime. The minimum performance standards are 2 mW/cm^2 for microwave ovens prior to purchase and 5 mW/cm^2 after purchase. Both levels are measured at 5 cm from the external surface of the oven. A second facet of the FDA/BRH microwave oven performance standard involves criteria for a mandatory system of door interlocks.[9]

The ANSI standard is in the process of being revised. The current proposed revision involves a frequency dependent standard keyed to the whole body specific absorbtion rate of RF energy in man.[10] In developing this standard, the ANSI C-95.4 subcommittee worked initially in subgroups divided by type of professional expertise (e.g., electrical engineering, biological sciences) and reviewed the existing research in the RF bioeffects. In their review, they eliminated all research findings which were either based on questionable test methodology or contained insufficient descriptions of the test methodology used during the research.[11] At the end of this screening process, only a handfull of research findings remained (figure 14); and these grouped themselves in a pattern consistent with the SAR curve (Figure 15)[12].

From this finding they developed the approach of a frequency dependent standard ranging largely from 1-5 mW/cm^2 (Figure 16). Some controversy remains about this frequency dependent approach. Among the unresolved issues are how to handle partial body exposures such as might occur to the groin area of an RF sealer operator or near the eye of someone operating a walkie talkie. A second issue that has been difficult to resolve involves the handling of intermittent exposure from either pulsing or rotating sources.

Western Europe: The standards of the UK, France and the

Federal Republic of Germany largely parallel the U.S. The Canadian Standard also did until it was recently tightened[13].

Sweden also tightened their standard in 1976, but note that though the Swedish Standard is also frequently dependent, the shape of the frequency dependence curve is not the same as the proposed ANSI Standard. The Swedish Standard by and large allows 5 mW/cm^2 where the ANSI Standard allows 1 and vice versa[14].

Eastern Standards:

USSR: The USSR Standards have been the subject of some confusion. The confusion involves not only how the standards came to be set as discussed earlier, but just what the standards are. Both 5 uW/cm^2 and 1 uW/cm^2 [15] have been cited as the Soviet exposure level to the general population. However, the existing Soviet Standards, (i.e. both those relating to general public exposure and those relating to occupational exposure) do not extend to either military emitters or military personnel. There is also some doubt as to whether common Soviet measuring devices can measure fields this small and whether there is any program to measure RF fields among the general public to ensure compliance[16].

The Soviet occupational standard is measured primarily in volts per meter below a frequency of 300 MHz. The allowable amounts range from 50 V/m from 60 KHz-1.5 MHz to 5 V/m from 50-300 MHz. From 300 MHz to 300 GHz the Soviet standard allows up to an exposure of 1 mW/cm^2 for up to 20 minutes exposure. The basic standard is an average exposure of no more than 10 uW/cm^2 throughout the day or 100 uW/cm^2 (0.1 mW/cm^2) from rotating or scanning sources. Again, it appears military personnel and military equipment are exempt from this standard[17].

Czechoslovakia: These standards were adopted in 1968 and also consider both level of energy and time. The basic standard is 2.5 uW/cm^2 average exposure for the general population over a 24 hour period or 1 uW/cm^2 average exposure over a 24 hour period to pulsed radiation. The occupational standard allows an exposure to 10 times the general population standard but, limited to the duration of the 8-hour work day[18].

Poland: The basic occupational standard is 10 uW/cm^2 with increased levels of exposure allowed for shorter durations of time. The Polish occupational standard also includes the following specific provision: "No person shall remain in an electromagnetic field of an intensity exceeding 1 mW/cm^2 unless in cases of emergency and on the condition that special protective measures, as decided for each case

by the person in charge of the undertaking, are taken[19].

Other Standards

People's Republic of China: China has adopted a temporary standard of 50 uW/cm^2 for all frequencies but allows increased levels of exposure for shorter durations[20].

FOOTNOTES

1. United States Air Force, "Draft Supplement to the Over The Horizon Backscatter Radar (OTHB) Environmental Impact Statement", (1981) at C-6.

2. *Id.* at C-11.

3. *Id.* at C-6

4. *Id.* at C-6, Department of Commerce, National Telecommunications and Information Administration (NTIA),"Fifth Report on 'Program for Control of Electromagnetic Pollution of the Environment: The Assessment of Biological Hazards of Nonionizing Electromagnetic Radiation' ", (1979) at pages 81 *et seq*.

5. OTHB, *op cit*. at C-8. See also the case of *Swimline Corp*., *infra*, Chapter VI, note 49.

6. *Infra*, Chapter VI notes 1-38.

7. 21 C.F.R. part 1030.

8. Vol. 45 Federal Register at page 50359 *et seq*. (July 29, 1980.

9. 21 C.F.R. part 1030.

10. Several interviews and discussions with John C. Mitchell, USAF School of Aerospace Medicine, Brooks AFB, TX.; and member of the ANSI C-95.4 subcomittee (August 1979 - June 1981). Letter from Arthur W. Guy, Chairman, ANSI C-95.4 subcommittee (June 5, 1979).

11. *Id.*

12. *Id.*

13. OTHB, *op cit*., at page C-10 and at Table C-1.

14. *Id.* at page C-12 and at Table C-2.

15. 1 uW/cm^2 was cited in the FCC's Notice of Inquiry, Docket No. 79-144 (1979) , but it is not entirely clear whether this standard is just being discusssed in the USSR, and whether the prior general exposure standard of 5 uW/cm^2 is still the official standard.

16. Interview with Christopher H. Dodge, Congressional Research Service, (January, 1979).

17. Lerner, "RF Radiation: biological effects", IEEE

Spectrum (December, 1980); OTHB op cit. at page C-11.

18. NTIA, op cit. note 4.

19. Id.

20. Lerner, op cit. note 17.

Chapter VI

LEGAL BASIS FOR REGULATION

The overall purpose of this thesis is an attempt to determine whether there is a need to regulate electromagnetic radiation -- and if so how it should be done and whether an additional statutory/regulatory framework is needed to accomplish that goal.

To this point we have seen that electromagnetic radiation can clearly cause adverse health effects. It appears though that as to currently documented health effects, the general populace is not subjected to levels of electromagnetic radiation sufficient to put them at risk. So too, neither does it appear that there is any widespread risk to American workers in their workplaces.

But because electromagnetic radiation clearly can cause a health risk; because there appears to be an increasing trend of scientific studies which tends to show effects from electromagetic radiation not previously known; and because of the continuing increase in the number of electromagnetic radiation emitters -- not only in business and industry, but in the home and and for recreational purposes as well -- prudence would seem to indicate that there should be some control on electromagnetic radiation emissions. This appears particularly true for those in close proximity to an emitter, either the unsuspecting worker who may be exposed or the member of the general public who may use an electromagetic radiation emitter (e.g. CB radio, microwave oven) without fully understanding the consequences of exposure to electromagnetic radiation.

The purpose of this final section of the paper will be to examine the existing stautory basis which would allow regulation of electromagnetic radiation; the agencies currently empowered under this statutory basis to regulate; the extent to which they have implemented their authority in this area; and some suggestions as to how they can work effectively together in the near term in regulating electromagnetic radiation given the still unsettled scientific understanding as to adverse health effects

CURRENT STATUTORY AUTHORITY

Department of Health and Human Services (formerly Health Education and Welfare), Food and Drug Administration, Bureau of Radiological Health (BRH)

The only statute created to in part specifically deal with electromagnetic radiation is the Radiation Control for Health and Safety Act (RCH&S Act) of 1968[1]. The impetus for the act came from reports in 1967 finding that a number of

color television sets were leaking X-ray radiation far in excess of acceptable safety limits. This and other similar factors led President Johnson to include a request for control of radiation from electronic products in his State of the Union address on January 17, 1968[2] and again in his February 6, 1968 message on consumer protection[3]. By October 11 the legislation was passed by both houses.

The prime focus of the act is on a system for setting performance standards on "electronic products" which are defined as:

> (A) any manufactured or assembled product which when in operation ,(i) contains or acts as part of an electronic circuit and (ii) emits (or in the absence of effective shielding or other controls would emit) electronic product radiation, or (B) any manufactured or assembled article which is intended for use as a component, part or accessory of a product in clause (A) and which when in operation emits (or in the absence of shielding or other controls would emit such radiation[4].

" Electronic Product Radiation" is further defined to include "ionizing or non-ionizing electromagnetic or particulate radiation or . . . any sonic, infrasonic, or ultrasonic wave which is emitted from any product as the result of the operation of an electronic circuit in such product[5]."

Noteworthy in these definitions is that they collectively obviate the need to consider the kind of radiation being emitted (e.g. ionizing or non-ionizing, RF or microwave, X-ray or visible spectrum, alpha or beta). Rather, the act focuses on the source of the radiation (i.e., electronic products) with a sweeping definition so as to subsume seemingly all potential sources of man-made or other forms of electromagnetic radiation.

The Act makes the then Secretary of Health Education and Welfare (now Health and Human Services) responsible to carry out a multi-faceted program "designed to protect the public health and safety from electronic product radiation"[6]. The act specifies six mandatory requirements for the Secretary under this program:

1. A requirement to develop and administer performance standards for electronic products;

2. Conduct activities to minimize the emissions of and exposure of people to, unnecessary electronic product radiation;

3. Maintain liaison and interchange information with state federal and private activities including educational institutions industry and labor interests on present and future electronic product radiation;

4. Research into exposure to electronic product radiation and intense magnetic fields;

5. Research and developing techniques to minimize exposure to electronic product radiation; and,

6. A particular requirement to consult and maintain liaison with the Secretaries of Commerce, Defense, and Labor and the Chairman of the Atomic Energy Commission on matters involving testing for[7] elctronic product radiation and developing standards.

As noted above, the key to the program to control electronic product radiation under the act comes from the setting of performance standards under §263f of the act as codified. This section permits the Secretary to promulgate, through formal rulemaking under Title 5, U.S. Code, performance standards regarding the emission of electronic product radiation. These standards may include (in addition to absolute requirements as to the amount of radiation which may be emitted) standards regarding: measurement and testing; warning signs; and specifying instructions on installation, operation, and use of a product.

In addition to requiring that the standards be promulgated under the rulemaking procedures of Title 5, the act provides some other checks and requirements before the Secretary may issue standards. First the statute requires creation of a Technical Electronic Product Radiation Safety Standards Committee which must be consulted before the Secretary may prescribe standards. The Committee is composed of 15 persons: five from governmental agencies (seemingly with a mandatory requirement that there be representation from State and Federal governments); five persons to be selected from "affected industries after consultation with industry representatives; and five members selected from the "general public" including at least one representative from organized labor.

All members of the Committee are required by statute to be "technically qualified by training and experience in one or more fields of science or engineering applicable to electronic product radiation safety. The members are appointed to the Committee by the Secretary, "after consultation with public and private agencies concerned with the technical aspect of electronic product radiation safety".[8] In addition to consulting with the Committee, the

Secretary must also consult with, " Federal and State departments and agencies having related responsibilities or interests and with appropriate professional organizations and interested persons including representatives of industries and labor organizations which would be affected by such standards."

Beyond the consultation requirements, the Secretary is directed in proposing standards to consider:

1. The latest relevent scientific and technical data;
2. Current standards of other Federal agencies or public or private groups with expertise in the area;
3. Reasonableness and technical feasibility of the proposed standard considering the particular electronic product involved;
4. Whether the standard is adaptable to the need for uniform testing and measurement equipment and procedures; and,
5. Where a component or accessory is involved, the performance of that element in the manufactured or assembled product.[9]

Lastly, in proposing a product performance standard, the Secretary must also determine that the standard is "necessary for the protection of the public health and safety."[10]

Standards promulgated under this section do not apply to products destined solely for export if the product otherwise complies with the standards of the importing nation[11]. There is also a procedure whereby products purchased for use by other federal agencies may be exempted from the performance standard requirements[12].

Once performance standards have been established for a product, the manufacturer of the product must either test each product or subject the product to a testing program. The manufacturer must then place a lable on the product before shipment to a distributor or dealer certifying that the product meets the standard[13]. Though the Secretary does not have the right to review and affirmatively approve the manufacturers' testing programs, he does have the right to disapprove a testing program for either inadequately safeguarding against electronic product radiation or for failure to ensure that products comply with the prescribed standards[14].

To date the only performance standard promulgated for devices emitting radiation in the microwave range of frequencies has been the standard governing microwave ovens[15], although FDA is well underway in also establishing a standard for diathermy devices[16]. These standards, obviously have been very slow in coming. The microwave oven

standard was issued in 1970 and has only received some minor revision since that time[17].

The development of a performance standard for diathermy devices has been underway since 1974[18]. A 1979 GAO report documents that while the FDA examined about 40 catagories of products in the early 1970's for possible regulation, little research into product catagories has been done of late[19]. The GAO found that FDA looks to three factors in identifying radiation emitting products for possible performance standard promulgation: risk, public interest and practicality of correcting the problem.

The risk consideration includes the potential of injury, illness or economic loss to the consumer. Public interest considerations include the extent to which a consumer may be unable to determine the degree of risk presented by a product and the need for special protection of certain classes of consumers such as children or the elderly. The practical concerns faced by FDA include the overall lack of scientific knowledge, the agency's authority to take action, and lastly the pragmatic "size of the problem as it relates to agency priorities[20]."

Another problem is the inherent slowness of the procedures required by the 1968 act. The comprehensive co-ordination provisions in addition to the requirement to use the formal rulemaking procedures under Title 5 also include a requirement that a standard may not take effect until at least one year after issuance.[21]

Another facet of the radiation control program under the act is a procedure to notify purchasers and the government of product defects which may either cause the product to exceed the established emissions standards, or may "relate to safety of use of such product by reason of the emission of electronic product radiation[21]. The duty to notify occurs in two instances; 1) where the manufacture discovers a defect which presents a concern for safety or causes the product to exceed standards[22]; or 2) where the manufacturer is notified by the Secretary of such a condition[23]. Under the statute the manufacturer is required to notify both the distributors and dealers of the product and all the consumer-purchasers of the product known to him[24].

The Secretary is further authorized by the statute to issue regulations requiring manufactures and dealers to obtain sufficient information to locate the first consumer-purchaser of the product[25] and has in fact, done so[26]. Notifications under the statute are required to be made by certified mail[27], must contain a clear statement of the nature of the defect, and the the right under the statute to secure correction of the defect[28].

The statutory provisions on notification also include a procedure whereby a manufacturer can apply to the Secretary for a waiver of the notification requirement upon bearing the burden of proof that the nature of the defect is such that it will not create a significant risk of injury[29].

The RCH&S Act obligates a manufacturer to provide certain remedies to purchasers of electronic products later discovered to have defects requiring notification[30]. The Act spells out three alternative remedies: 1) to repair the product at no cost to the purcaser("no cost" specifically including that the manufacturer will assume the cost of transportation--noteworthy when one considers that the average microwave oven weighs approximately 75 lbs.) 2) replacing the defective product with a like product free from defects; or 3) refunding the cost of the product[31].

Under the regulations implementing this statutory provision the decision as to which of the alternative corrective actions will be used and how it will be implemented is not left entirely to the discretion of the manufacturer. Rather, the manufacturer must elect an option and then provide a written plan to the Secretary as to how that alternative is proposed to be implemented. The program can then be implemented by the manufacturer only after the plan is approved by the Secretary. In approving the plan the Secretary must find that it will "expeditiously and effectively" fulfill the manufacturer's obligations under the statute and implementing regulations in a way "designed to encourage the public to respond to the proposal"[32].

Electronic products imported into the United States are also covered by the act. Section 263j(a)(1) of the act as codified specifically makes it unlawful to import or otherwise deliver or introduce into commerce an electronic product which does not meet an applicable performance standard promulgated under §263f. Section 263h of the act implements this program in more detail by specifying a co-operative program between Treasury and the now Department of Health and Human Services for the screening of products coming into the country for sale[33].

Other sections of the act deal with specifically prohibited acts[34], enforcement procedures[35], an annual report to the Congress[36], a program of federal state co-operation[37], and establish federal supremacy for any performance standard promulgated under §263f[38].

In summary the RCH&S Act provides the general framework for a system of point source control of electromagnetic radiation. Such a system appears particularly appropriate due to the physics involved in the propagation of electromagnetic radiation , i.e. that the highest levels of radiation will occur closest to the emitter with the levels

of radiation (e.g. the measurments in mW/cm^2 or uW/cm^2) falling off rapidly with distance. A system of technology based point source control seems particularly appropriate for RFR emitters used by consumers (e.g., microwave ovens, Citizen's Band transmitters) who likely lack the sophistication and tools to ensure that there is no inadvertent exposure to unsafe levels of RFR radiation. The microwave oven standard is an example of such a system. It combines a scheme of RFR emission standards forcing design of the ovens adequate to meet the standards. This is re inforced by a system of certification and testing, further reinforced by mandatory design requirements (door interlocks), a program of placarding to warn consumers of the potentially dangerous nature of the units, and lastly a program of mandatory repair (at manufacturers' cost) for defective units. Here because the RFR emitters involved will be used by unknowing consumer- users in an environment free from control by either the manufacturer or a public health and safety body, there is a need to incorporate safeguards into the emitter itself.

The drawbacks to current use of the RCH&S appears to be the cumbersome statutory process for promulgating performace standards further clouded by the still sketchy scientific infomation as to the characteristics of electromagnetic radiation which actually tend to present a risk to human health. Further as discussed <u>infra</u>, such a system of technology based point source control is probably not required where there can be tight, enforceable, controls over the siting and use of RF emitters.

<u>Department of Labor, Occupational Safety and Health Administration (OSHA)</u>

The Secretary of Labor under the Occupational Safety and Health Act of 1970[39], is responsible for setting mandatory occupational safety and health standards[40] "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources[41]".

This general charter and its implementing statutory guidance[42] has led to promulgation of a voluminous collection of standards[43]. An attempt was made under OSHA to develop standards dealing with occupational exposure to non-ionizing radiation[44]. However since its inception this standard has been couched in terms of a "Radiation Protection Guide[45]" which is described as the " radiation level which should not be exceeded without careful considerations of the reasons for doing so[46]".

Though the OSHA guide is supposed to pertain to radiation in"that portion of the spectrum commonly defined as the radio frequency region which . . .include[s] the

microwave frequency region[47]," and pertains to both whole body and partial body irradiation[48], the limiting factor in the utility of the guide is that it has been held in the case of Swimline Corp.[49] to be just that-- a guide-- merely advisory as opposed to being mandatory in nature.

The OSHA non-ionizing radiation standard is based on the standard promulgated by the American National Standards Institute (ANSI) in 1966[50]. As of this date the OSHA non-ionizing radiation standard remains only advisory in nature. An attempt is being made through the National Institute for Occupational Safety and Health (NIOSH) to develop a criteria document which can be used by Department of Labor to develop an enforceable OSHA standard[51]. This effort was initiated at the request of the Occupational Safety and Health Administration.

The effort formally commenced on December 23, 1976 with NIOSH's publishing a notice in the Federal Register soliciting public input to assist in developing the criteria document. In a follow-on notice published in the October 28, 1977 Federal Register, NIOSH indicated its intention to develop a recommended non-ionizing radiation occupational health standard.[52] To date however, only initial drafts of the criteria document and the proposed revised standard have been circulated for comment.

Another initiative which may lead to a binding occupational non-ionizing radiation standard is the on-going effort of the ANSI C-95 committee. This committee is charged with responsibility to review and either revise or re-issue ANSI's non-ionizing radiation exposure standard[52]. By ANSI rules this review and decision making process is to occur every five years. The last review commenced in 1979[53] and is still underway[54].

The current approach of the ANSI committee is to completely re-vamp the current standard rather than simply re-issue it (as discussed in Chapter V, supra). It has been this effort to substantially revise the standard in a manner that receives broad based approval from technical authorities that has principally contributed to the committee's delay in finishing its work[55].

Under the Occupational Health and Safety statute, the Secretary of Labor is specifically authorized to adopt "any national concensus standard" as a standard under the act[56]. Adoption of the 1966/1974 ANSI non-ionizing radiation standard is the source of the current OSHA guideline in 29 CFR §1910.97. However, for the administrator to adopt the revised ANSI standard as an enforceable OSHA standard, the ANSI standard, as revised, will have to be couched in mandatory language (i.e. shall) as opposed to advisory language (i.e. should)[57]. If the

revised ANSI standard contains language, mandatory in nature, the Secretary may proceed to adopt the ANSI standard in lieu of developing an OSHA standard based on the NIOSH criteria document.

An enforceable and enforced OSHA standard, as it could incorporate a combination of technology based point source control and constraints on manners of using the emitter, would seem to be the best regulatory scheme for control of RF radiation exposure in the workplace.

Environmental Protection Agency (EPA)

EPA is currently proposing to issue "guidance" regarding radio-frequency radiation under the authority of section 274(h) which was a 1959 amendment to the Atomic Energy Act of 1954[58]. According to the EPA staff[59], they envision such guidance as both setting standards for use of RF radiation by federal agencies (i.e. placing certain requirements on federal emitters most likely related to siting and exclusion fencing) and also have the guidance operate as setting a minimum level decision making criteria for federal agencies making decisions (e.g., granting permits, authorizing the use of certain frequencies) and otherwise regulating radio-frequency radiation emitters in the private sector.

The current plan is to issue an advanced notice of proposed rulemaking by December,1981, with the guidance and supporting documentation being issued in proposed form sometime in 1982[60].

The statutory basis upon which EPA proposes to issue the guidance is arguable at best with regard to radio frequency and other forms of non-ionizing radiation. The clear purpose of the Atomic Energy Act is to develop a program of federal control over atomic energy and other forms of ionizing radiation sources. As stated in the Congressional "declaration of policy":

> Atomic Energy is capable of application for peaceful as well as military purposes. It is therefore declared to be the policy of the United States that--
>
> (a) the development, use and control of atomic energy shall be directed so as to make the maximum contribution to the general welfare, subject at all times to the paramount objective of making the maximum contribution to the common defense and security; and
>
> (b) the development use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise.[61] (emphasis

added)

For the most part the findings and puposes section of the act do not address public safety and health concerns, but where they do, the concerns are clearly related to those stemming from concerns only about ionizing radiation and its sources:

> **§2012. Congressional Findings**
>
> . . .
>
> (d) The processing and utilization of source, byproduct, and special nuclear material must be regulated in the national interest and in order to provide for the common defense and security and to protect the health and safety of the public.
>
> (e) Source and special nuclear material, production facilities, utilization facilities are affected with the public interest, and regulation by the United States of the production and utilization of atomic energy and of the facilities used in connection therewith is necessary in the national interest to assure the common defense and security and to protect the health and safety of the public.[62]
>
> . . .
>
> **§2013 Purpose of Chapter**
>
> . . .
>
> (d) a program to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes to the maximum extent consistent with the common defense and security and with the health and safety of the public[63];

So too do the definitions in the act also make clear that only ionizing radiation and its sources are intended to be controled. "Atomic energy" is defined as " all forms of energy released in the course of nuclear fission or nuclear transformation [64]." "Byproduct material" is defined as:

> (1) any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to radiation incident to the process of producing or utilizing special nuclear material, and (2) the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content [65].

"Source material" means:

> (1) uranium, thorium, or any other material which is determined by the Commission . . . to be source material; or (2) ores containing one or more of the foregoing materials, in such concentration as the Commission may by regulation determine. . .[66].

"Special nuclear material" is also defined in terms of various forms of radioactive substances like plutonium and enriched uranium isotopes[67].

EPA was not originally included in the act, but assumed certain limited responsibilities as a result of Reorganization Plan number 3 of 1970[68] which abolished the old Federal Radiation Council and transferred its functions to EPA[69] which was also created by that reorganization plan. The plan also appears to underscore that whatever authority EPA gained under the reorganization plan with regard to radiation is limited to ionizing radiation. Specifically, while the plan transferred some functions of the Bureau of Radiological Health (BRH) to EPA, BRH's responsibilities under the Radiation Control for Health and Safety Act of 1968 were not transferred.

Responsibilities specifically retained included BRH's regulation of "radiation from consumer products, including electronic product radiation" and "research,technical assistance and training" related to that regulation[70]. Transferred to EPA under the reorganization plan were certain responsibilities for establishing "generally applicable environmental standards for the protection of the general environment from <u>radioactive material</u>", which was further defined to mean limits on radiation exposures or levels, or concentrations or quantities of radioactive material" that formerly rested with the Atomic Energy Commission under the 1954 Atomic Energy Act[71].

In sum, control over protection of the general environment from <u>ionizing radiation</u> was specifically transferred to EPA, but control over non-ionizing radiation stemming from the RCHS&A act was specifically retained at BRH.

Section 274 of the Atomic Energy Act specifically deals with Federal-State co-operation and contains its own statement of purposes for the section. Again, the statement of purposes for the section itself essentially relates to health and safety concerns about ionizing radiation and the materials emitting such radiation:

> (a) It is the purpoose of this section --
>
> (1) to recognize the interests of the

States in the peaceful uses of atomic energy, and to clarify the respective responsibilities under this chapter of the States and the Commission with respect to the regulation of byproduct, source, and special nuclear materials;

(2) to recognize the need, and establish programs for, cooperation between the states and the Commission with respect to control of radiation hazards associated with the use of such materials;

(3) to promote an orderly regulatory pattern between the Commission and the State Governments with respect to nuclear development and use and regulation of byproduct, source and special nuclear materials;

(4) to establish procedures and criteria for discontinuance of certain of the Commission's regulatory responsibilities with respect to byproduct, source and special nuclear materials, and the assumption thereof by the States;

(5) to provide for coordination of the development of radiation standards for the guidance of Federal agencies and co-operation with the States; and

(6) to recognize that, as the States improve their capabilities to regulate effectively such materials, additional legislation may be desirable.[71]

When the statute creating the Federal Radiation Council was originally passed, the Council was comprised of the Chairman of the Atomic Energy Commission, The Secretaries of Commerce, Defense, Health ,Education and Welfare, and Labor, and others as designated by the President[72].

The Senate Report[73] on section 274 notes specifically that the purpose of the section is limited to federal state co-operation regarding "the materials already regulated by the Commission under the Atomic Energy Act of 1954; namely: byproduct,source and special nuclear materials[74]."

As described in the Senate report, the Federal Radiation Council under the Act was to be similar to the Radiation Council which had then been recently created under an

Executive order by President Eisenhower. Though there is one reference in the Senate Report that the new Council would have a basic modification in function from that created in the Executive Order[75], however there is no elaboration as to what that modification was to be.

The Council created by President Eisenhower in Executive Order 10831, though, was specifically limited in its area of responsibility to ionizing radiation:

> Sec. 2. The Council shall advise the President with respect to radiation matters directly or indirectly affecting health, including matters pertinent to the general guidance of executive agencies by the President with respect to the development by such agencies of criteria for the protection of humans against ionizing radiation applicable to the affairs of the respective agencies. The council shall take steps designed to further the interagency coordination of measures for protecting humans against ionizing radiation[76]

Admittedly, it could be argued that the decision by Congress to exclude the term "ionizing" as modifying the "radiation" which was to be the responsibility of the Council, evidences that Congress intended to broaden the responsibilities of the Council created under the Act beyond "ionizing radiation". But the better construction of the role of the Council would appear to have Congress intending to limit the role of the Council to those matters (and forms of radiation) which were the subject of the Act itself--i.e. the radiation caused by source,byproduct and special nuclear material.

What we then have left at this point is an attempt by EPA, as successor to the Federal Radiation Council(FRC), to issue binding guidelines on Federal Agencies for a type of radiation outside the jurisdiction of the original FRC. As presented by EPA staff members, the procedure for issuing this guidance would have it ultimately approved by the President before it became effective. It is not clear whether they intend for it to be issued as an Executive Order. If so, it clearly would be binding on Federal Agencies, at least in so far as operation of Federal Agency emitters is involved.

But given the shakey statutory basis by which EPA could issue guidance which applied to private radio frequency radiation sources, it is doubtful that EPA's guidance could be obligatory in the decision making processes of agencies such as the FCC (in determing uses of the frequency spectrum and the licensing of emitting devices) or BRH (in exercising

it's responsibilities under the Radiation Control for Health and Safety Act of 1968.)

Federal Communications Commission (FCC)

Under the Communications Act of 1934[77] Congress created the Federal Communications Commission with responsibility in part " for the purpose of promoting safety of life and property through the use of radio communication[78]." Further, the act broadly describes the type of activity regulated, stating that:

> "The provisions of this chapter [the Act as codified at §151 et seq.] shall apply to all interstate and foreign communication by wire or radio and all interstate and foreign transmission of energy by radio, which originates and/or is received within the United States, and to all persons engaged within the United States in such communication or such transmission of energy by radio. . . [79].

Broadly stated, the FCC has complete control over the propagation of non-ionizing radiation from all sources except Federal Government transmitters[80]. The FCC is concerned and somewhat uneasy regarding its appropriate role in the area of regulating radio frequency radiation from the perspective of adverse biological effects. In June 1979 the FCC issued a notice of inquiry[81] in this area stating:

> . . . The [FCC] is initiating this Inquiry to gather information and views that will assist it in establishing the course it should pursue in fulfilling its regulatory responsibility to promote communications by radio in light of the increased concern about the biological effects of radio frequency radiation.
>
> . . .
>
> . . . This Inquiry is therefore designed to serve two purposes. We hope to gather information to: 1) assist us in determining whether it is appropriate to take any action under existing standards now applied by health and safety agencies; and 2) provide documentation so that we may adequately participate in any rulemaking proceedings of these other agencies to ensure any standard adopted adequately takes into account the impact of any proposal on the licensees and equipment we regulate.[82]

Discussing the FCC's statutory obligations the Notice rests its responsibilities both on the obligation to promote life and safety under the act as well as the broader responsibility to make available the use of radio "in the public interest."[83]

The term public interest stems from section 303 of the Act. Section 303 deals with powers and duties of the Commission and provides:

> Except as otherwise provided in this chapter, the Commission from time to time, as public convenience, interest and necessity requires shall--
>
> . . .
>
> (c) Assign bands of frequencies to the various classes of stations, and assign frequencies for each individual station and determine the power with which each station shall use and the time during which it may operate;
>
> (d) Determine the class of stations or individual stations;
>
> (e) Regulate the kind of apparatus to be used with respect to its external effects and the purity and sharpness of the emissions from each station and from the apparatus therein. . .[84].

The Commission, therefore has the power to regulate all the facets of non-ionizing radiation critical to concerns about potential harmful biological effects: frequency, power, siting and a specific reference to the potential external effects of the RF emissions.

In reality, the FCC is the one federal agency that currently has control over all sources of RF radiation owned in the private sector, and an arguable basis through its own organic act and through the National Environmental Policy Act[85] to regulate these sources from the standpoint of biological effects. As stated by the Commission in the Notice:

> . . .The Commission has licensed the millions of non-government transmitters now in use throughout the Nation and is granting additional licenses at an accelerating rate. In addition, under parts 15 and 18 of our Rules[86] we authorize microwave ovens, industrial heaters and many other types of unintentional radiating equipment. . . . The Commission's actions as a Federal Government

regulatory agency must be consistent with the dictates of our organic statute and the National Environmental Policy Act. . . The Communications Act requires us to promote the use of radio communications service". . . for the purpose of promoting safety of life. . ." and to exercise our power" . . . as the public convenience, interest, or necessity requires." . . . If another agency of the U.S. Government, such as the Environmental Protection Agency (EPA) or Occupational Safety and Health Administration (OSHA) promulgates non-ionizing exposure standards that we thought might be exceeded by an authorized facility, it would be incumbent upon the Commission to consider that agency's determination in our licensing and certification requirements.

Moreover, in addition to these implied responsibilities under the "public interest" standard, the Commission, as a Federal Agency, has certain explicit duties under NEPA. Section 102(2)(c) of that statute requires all federal agencies to consult with and obtain the comments of expert federal agencies before taking any major action significantly affecting the quality of the human environment. EPA and OSHA (as well as BRH) are the requlatory agencies in the biological effects area. If a contemplated Commission action might create a situation where the resulting RF radiation levels would exceed an exposure guideline or standard by one of those agencies, we would be required to consult the concerned agency before acting.

Following such consultation, the Commission may have to prepare an environmental impact statement that would become part of the record on which the commission bases its decision. The Commission's present policy is to require licensees and manufacturers of authorized equipment to observe applicable exposure safety standards. . .

The Commission, as well as the affected industries, cannot ignore the possibility that one of the health agencies may promulgate stricter standards for radio frequency energy emission . . . or for RF radiation exposure where excessive power densities could pose a potential biological hazard to people. In that event, the Commission must consider those new standards with the possible result that some of these entities will be required to adjust their operations or equipment accordingly[87].

The reference to the FCC's obligations under NEPA is particularly interesting given another FCC proposal, this to promulgate new NEPA implementing regulations[88] in light of the NEPA implementing regulations of the Council on Environmental Quality[89].

While the FCC's "Notice of Inquiry" discusses their concern for the potential biological hazards of RFR, their proposed NEPA regulations do not reflect that concern. Perhaps the only "environmental concerns" reflected in the proposed rules relate to aesthetics of site specific facilities and those considerations mandated by other stautory and regulatory authority (e.g. wilderness and wildlife areas and construction in wetlands). As proposed there are six instances in which proposed facilities would be analyzed under an "environmental assessment"[90]:

> (1) Facilities that are to be located in an officially designated wilderness area or in an area whose designation as a wilderness area is pending consideration.
>
> (2) Facilities that are to be located in an officially designated wildlife preserve or in an area whose designation as a wildlife preserve is pending consideration.
>
> (3) Facilities that will affect districts,sites, buildings,structures or objects, significant in American history, architecture, archeology or culture, that are listed in the National Register of Historic Places or are eligible for listing . . . .
>
> (4) Facilities to be located in areas that are recognized either nationally or locally for their special scenic or recreational value.
>
> (5) Facilties to be located in a floodplain.
>
> (6) Facilities whose construction will involve extensive change in surface features (e.g. wetland fill, deforestation or water diversion). In the case of wetlands on Federal property, see Executive Order 11990

The proposed Commission rules then go on to explain that actions other than those cited above are proposed to be classified as "catagorical exclusions" within the meaning of 40 CFR §1508.4[91] and are therefore excluded from futher environmental consideration. The proposed rules do go on to note four catagories of facilities which are " more likely

than other lesser facilities" authorized by the Commission to have significant environmental effect: "1) underground cable and wave guide routes and aerial transmission lines; 2) antenna towers or supporting structures exceeding 300 feet in height; 3) AM directional arrays without regard to height; and, 4) satellite earth stations having an antenna exceeding 30 feet in diameter."[92] But here again the Commission's concern is based on considerations like aesthetics and not on concern about potential hazards from RF emissions. A note to the proposed Commissission rule provisions, just discussed, states:

> The provisisons of this paragraph do not encompass the installation of additional cable over existing ground cable routes or the mounting of microwave, FM, or television antennas or other antennas comparable thereto in size on an existing building or antenna tower. The use of existing routes, buildings, and towers is an environmentally desireable alternative and is encouraged. The provisions of this paragraph also do not apply to facilities located in areas devoted to heavy industry or to agriculture that are operated in support of the industrial or agricultural enterprises with which they are associated.[92] (emphasis added)

The FCC's true "environmental" concern is evident. While they express an environmental concern about large projects, particularly those which are going into areas where there previously have been no communications type equipment, they are evidently not concerned in their proposed regulations with the ramifications of RFR emissions. Recommending adding additional RFR emitting sources to existing emitting structures as the "environmentally desireable alternative" is just the opposite of what one would do out of a concern for reducing overall levels of RFR emissions in the area[93].

So too do comments regarding this section not applying to emitters being located in industrial areas belie a concern about potential adverse effects from RFR. It is the industrial area, above all, that may be subject to additional RFR emissions (and hence have a higher potential for adverse health effects due to RFR) from increasingly prevalent use of RFR emitters in industry and also, an increased likelihood of additive RFR effects from reflections off metallic surfaces, likely also more prevalent in the industrial environment.

The lack of regard for potential harmful effects of RFR becomes even more apparent in the next paragraph in the FCC's Federal Register issuance[93], where they further

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elaborate on those instances when a facility in one of the four catagories of large facilities is " extremely unlikely to have environmental consequences and are classified as catagorical exclusions from environmental processing requirements." Therefore not even an environmental assessment is normally required in instances including:

> (1) The construction of an antenna tower or supporting structure in an established "antenna farm" (i.e., an area in which similar antennas are clustered, whether or not such area has been officially designated as an antenna farm).
>
> (2) The modification of existing or authorized facilities, provided such modification does not involve a site change or a substantial increase in tower height.

Again, the concern of the FCC is for aesthetics, or at the least compatible land uses and not for the environmental implications of RFR emissions. By catagorically excluding the antenna farm from environmental review, they forego perhaps the only clear opportunity for a federal agency to address the implications of additive RFR emissions from multiple sources. Similarly, their proposal to catagorically exclude from consideration "environmental" implications of a change to a facility so long as it" does not involve a site change or a substantial increase in tower height", also underscores that RFR emissions are not included in the FCC's interpretation of actions " significantly affecting the quality of the human environment."

Further, the FCC's concerns in implementing NEPA only go to site specific, mostly new construction type activities. They go on through out the remainder of the proposed regulations to ignore the other types of activities of the FCC such as approval of new uses of the frequency spectrum including approval of new types of emitters including those in the ISM area.

Notwithstanding the tenor of these proposed FCC rules in ignoring the implications of RFR emissions, from an "environmental standpoint" it would be even worse if Commissioner Abbott Washburn had his way. In a dissenting statement following the proposed rules, he writes:

> The preparation of written environmental assessments is far afield from the business of this Commission. None of us here knows anything about environmental protection. The rule changes in this Notice of Proposed Rule Making unquestionably will result in increased workload

> for our already overburdened staff. Time and effort spent in unfamiliar areas areas by personnel faced with heavy backlogs in processing applications detracts from the Commission's major mission:". . .to make available, so far as possible, to all people of the United States a rapid, efficient, nationwide, and world-wide wire and communication service. . ."
>
> I would hope that parties commenting on this Notice will consider seriously the impact of these proposed additional requirements on the timely execution of our primary duties to the public.
>
> We are not compelled by law to take on this additional burden, nor do communications facilities impact on the environment to any appreciable extent. Where they do, it is largely in the aesthetics area.
>
> Precious FCC person-hours ought not to be diverted to this.[94]

In summary, because of the nature of RFR emissions (e.g. the extent to which frequency,modulation and emitted power, relate to SAR and to potential bioeffects) a system of point source control based around siting considerations would seem advisable. FCC has existing authority to adopt such a scheme in furtherance of a combination of its existing statutory authority under the Communications Act and the supplemental authority under the National Environmental Policy Act to consider the environmental consequences of the commission's actions. To date however the FCC has chosen to all but ignore the implications of RFR on the "quality of the human environment."

Electromagnetic Radiation Management Advisory Council (ERMAC)

No discussion of Federal activities involved in the area of biological effects of electromagnetic radiation would be complete with out at least some reference to ERMAC. As opposed however to those agencies just discussed, ERMAC has no statutory authority. However ERMAC, particularly when it was attached to the Director of Telecommunications Policy within the Executive Office of the President, was considered the principal resource body and advisor for the federal government as a whole on RFR bio-effects.

ERMAC was established in December, 1968 to provide advice to first the Director, Office of Telecommunications Management and then the successor Director, Office of Telecommunications Policy. Both activities were then located within the Executive Office of the President. Through Executive Order 12046, March, 1978, most of the

duties of these agencies were transferred to the National Telecommunications and Information Administration under the Department of Commerce. ERMAC's charter was modified to have it then advise the Secretary of Commerce through the Assistant Secretary for Communications and Information. In short, ERMAC moved from center stage in the government bureaucracy to if not left field, a place from which left field can be seen.

Nonetheless, ERMAC's charter does give them specific authority to:

> [A]dvise the Secretary of Commerce on side effects and the adequacy of control of electromagnetic radiations [sic] arising from telecommunications activities. It will review, evaluate, and recommend measures to investigate and mitigate potential undesireable effects on the environment. Its objectives include:
>
> (a) the review of Government and non-Government activities bearing upon the adequacy of control of electromagnetic applications which may involve directly or indirectly the production of radiant energy in any portion of the spectrum capable of causing harmful biological effects, or harm to equipment and material . . . .[95]

By and large ERMAC today is a toothless tiger. It has no permanent staff, a trivial budget, no real control of allied research and other activities of fellow federal agencies, and is largely buried in the basement of the cabinet department with the reputation for being the holding activity for a grab-bag assortment of federal functions without a "real place" in the day to day working of the government.

Interesting however is the amount of deference , notwithstanding paid to the ERMAC by staffers of several federal agencies (e.g. EPA, NIOSH, Veterans' Administration-- albeit not all agencies involved in RFR use, bioeffects research and standard setting.) who collectively ,by their actions, set Federal Policy in this area. Perhaps justifiably so. ERMAC's charter does establish them as the Federal Government's "titular experts" in the area of RFR bio-effects. As such their co-operation and endorsement of any proposed federal safety standard would appear critical, as a practical matter, to ensuring that such a standard would become legally enforceable. ERMAC would certainly attempt to issue a report and recommendation on any proposed standard. A negative report, or the more likely outcome of ERMACs inability to agree on a recommendation, would likely have a chilling effect on most agency administrators considering promulgating a final standard in as controversial and financially sensitive area such as this.

FOOTNOTES

1. PL 90-602, 42 U.S.C 263b et seq.

2. Letter from Willard Wirtz, Secretary of Labor, April 12 1968 to Senator Warren G. Magnuson, Chairman, Senate Commerce Committee. 1968 U.S. Code Cong. and Admin. News, Vol 3 at page 4347.

3. Letter from Ralph K. Huitt, Acting Secretary, Department of Health Education and Welfare June 14, 1968 to Senater Warren G. Magnuson, Chairman Senate Commerce Committee. U.S. Code Cong. and Admin. News 1968 Vol. 3, at page 4330

4. 42 U.S.C. 263c(2)

5. 42 U.S.C. 263c(1)

6. 42 U.S.C. 263d

7. 42 U.S.C. 263d(a)

8. 42 U.S.C. 263f(f)(1)(a)

9. 42 U.S.C. 263f(a)(1)(A-E)

10. 42 U.S.C. 263f(a)(1)

11. 42 U.S.C 263f(a)(3)

12. 42 U.S.C 263f(a)(5)

13. 42 U.S.C..263f(h)

14. Id.

15. 21 C.F.R. part 1030. Regulations also exist for electronic products emitting ionizing radiation (21 C.F.R. part 1020) including tevlevisions and x-ray systems; light emitting devices (e.g., lasers, sunlamps, and high-intensity mercury vapor lamps) (21 C.F.R. part 1040); and, ultrasonic devices (21 C.F.R. part 1050)

16. Microwave News, February 1981 at page 4.

17. General Accounting Office (GAO) Report HRD 79-4 Mircowave Radiation: More Protection Needed, 1979 at page 8; and notes following 21 CFR 1040.10.

18. Id. at page 17.

19. Id.

20. _Id_. at page 8.

21. 42 U.S.C. 263g, 21 CFR part 1003

22. 42 U.S.C. 263g(a)(1)

23. 42 U.S.C. 263g(e)

24. 42 U.S.C. 263g(a)(2)

25. 42 U.S.C. 263i(f)

26. 21 CFR part 1002, subpart E. Another interesting facet of part 1002 is the self reporting requirement for RFR exposure incidents in subsection C (§1002.20). This section requires a manufacturer with " reasonable grounds for suspecting" that an "accidental radiation occurrence" has taken place to report to the Director of the Bureau of Radiological Health. What consitutes an " accidental radiation occurrence" is not clearly defined in the regulations, but appears to include all instances where there has been a equipment malfunction allowing irradiation of an individual in excess of a performance standard or any other case of a substantial radiation. Under the regulations, the BRH Director has the right to have the manufacturer disclose the names of the persons exposed, the product involved and what if any corrective action has been taken. BRH has been including information gathered from these reports in the annual report to Congress required by §2631 of the act. From 1970 to 1978 they received 139 such reports from this regulatory requirement and from other sources involving exposure of 165 persons to electromagnetic radiation. Devices involved included microwave ovens (the most frequent source with 102 reports), microwave generators, diathermy devices, RF sealers and radars, (1978 Annual Report, _Administration of the Radiation Control for Health an Safety Act of 1968_ U.S. Department of Health Education and Welfare,(April 1, 1979).

27. 42 U.S.C. 263g(b)

28. 42 U.S.C 263g (b,f)

29. 42 U.S.C. 263g(a)(2), 21 CFR part 1003, subpart D

30. 42 U.S.C. 263g(f)

31. _Id_.

32. 21 CFR §1004.6

33. 42 U.S.C. 263h, 21 CFR part 1500

34. 42 U.S.C. 263j

35. 42 U.S.C. 263k

36. 42 U.S.C. 263l

37. 42 U.S.C. 263m. This section includes authority to use state personnel "for the purpose of conducting examinations, investigations and inspections."

38. 42 U.S.C. 263n. This section prohibits a state or a political subdivision of a state from adopting or continuing in force a performance standard for electronic products different than the federal standard, with the specific exception that the state or political subdivision may apply a more stringent standard on products procured for their own use. This section seemingly does not limit a state or local government from adopting a standard that would control the ambient amount of electromagnetic radiation in a region either through licensing of sources or some other scheme to control the quantity of emitters and their location.

39. P.L. 91-596, 29 U.S.C. 651 et seq.

40. 29 U.S.C. 651(b)(3)

41. 29 U.S.C. 651

42. 29 U.S.C. 655

43. 29 CFR parts 1910, 1913-1918, and 1926-1928.

44. 29 CFR §1910.97. There is also a non-ionizing radiation standard pertaining to the construction trades (29 CFR 1926.54); however it only deals with hazards associated in the construction industry.

45. 29 CFR §1910.97(a)(2)

46. 29 CFR §1910.97(a)(1)(iii)

47. 29 CFR §1910.97(a)(1)(i)

48. 29 CFR §1910.97(a)(2)(ii)

49. In Swimline Corp. :1975-1976 CCH Occupational Health and Safety Decisions ¶20,379 (decision of the Administrative Law Judge); 1977-1978 CCH Occupational Health and Safety Decisions ¶21,656, (decision of the Occupational Safety and Health Review Commission). The non-ionizing radiation guide of 29 CFR §1910.97 was held to be only advisory in nature. Swimline Corporation had been cited for allowing an employee to allegedly be exposed to electromagnetic radiation from an RF sealing machine in excess of the applicable 10 mW/cm^2 guideline. The judge found that the use of the term "should

not" in the standard rendered it advisory only in nature, whereas the use of the term "shall not" would have created a binding, mandatory standard. The judge went on to find that for this to be an enforceable standard it would have to, by definition (29 U.S.C. 652(8)), require the employer to meet certain conditions or adopt certain standards.

50. 29 CFR §1910.99

51. Fifth Report of the National Telecommunications and Information Administration, Department of Commerce, 1978 at page 84.

52. Id.

53. Id.

54. Mitchell and Guy, Chapter V, note 10, supra.

55. Id.

56. 29 U.S.C. 655

57. In Marshall v. Union Oil Co. of Calif., 616 F. 2d. 1113, (9 Cir. 1980) it was held that the Secretary of Labor improperly promulgated an OSHA standard where he sought to adopt an ANSI standard under the "national concensus standard procedure" but in doing so changed the "should" language of the ANSI standard to "shall" in the OSHA standard.

58. 45 Federal Register 16845, March 14, 1980; Presentation by Norman Hankin to the meeting of the Electromagnetic Radiation Management Advisory Council, Washington D.C. July 16, 1981. Section 274(h) of the Act as amended by P.L. 86-373 (42 U.S.C. 2021(h) currently provides:

> The Administrator of the Environmental Protection Agency shall consult qualified scientists and experts in radiation matters, including the President of the National Academy of Sciences, The Chairman of the National Committee on Radiatioon Protection and Measurement, and qualified experts in the field of biology and medicine and in the field of health physics. The Special Assitant to the President for Science and technology or his designee, is authorized to attend meetings with, participate in the deliberations of, and to advise the Administrator. The Administrator shall advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards and in the establishment and execution of programs of co-

operation with States. The Administrator shall also perform such other functions as the President may assign him by Exective order.

59. Hankin presentation, op cit.

60. Id. and presentation of David Jaynes.

61. 42 U.S.C. 2011.

62. 42 U.S.C. 2012.

63. 42 U.S.C. 2013.

64. 42 U.S.C. 2014(c).

65. 42 U.S.C. 2014(e).

66. 42 U.S.C. 2014(z).

67. 42 U.S.C. 2014(aa).

68. 35 Federal Register 15623, 84 Stat. 2086.

69. Id. at section 2 paragraph 7.

70. Id. at section 2 paragraph 3.

71. 42 U.S.C. 2021(a).

72. P.L. 86-373 paragraph (h).

73. U.S. Code Congressional and Administrative News, 1959 at page 2880.

74. Id. at 2874.

75. Id.

76. Id. at 1093.

77. 47 U.S.C. §151 et seq.

78. Id. at §151

79. Id. at §152. "Transmission of energy by radio" and "radio transmission of energy" are defined broadly to include ". . . both such transmission and all instrumentalities, facilities, and services incidental to such transmission."(Id. at § 153[d])

80. Id. at § 305. The act delegates this responsibility for Federal emitters to the President. Currently the the

bulk of responsibility has been redelegated through the Department of Commerce to its subsidiary National Telecommunications and Information Agency under E.O. 12046, March 27, 1978 as amended by E.O. 12148, July 20, 1979.

81. F.C.C. General Docket No 79-144, adopted June 7, 1979; released June 15, 1979.

82. Id. at paragraphs 1,3.

83. Id. at paragraph 11. The "public interest" duty stems from section 303 of the Act (47 U.S.C. 303) within the subchapter of the Act entitled " Special Provisions Dealing with Radio."

84. 47 U.S.C. 303(c-e).

85. 42 U.S.C. 4321 et seq.

86. 47 C.F.R. parts 15,18. Note at the time of the Inquiry Part 18 was in the process of being revised. This revision is still pending.

87. Notice of Inquiry, supra, paragraphs 12-15.

88. Vol.44 Federal Register at page 38913, July 3, 1979.

89. 40 CFR part 1500.

90. 40 CFR §1.1305(a) as proposed, note 88, supra.

91. 40 CFR §1.1305(b) as proposed, note 88, supra.

92. Note following 40 CFR §1.11305(b) as proposed, note 88, supra.

93. Recall Chapter II, the discussion of the "specific source environment" and that the highest readings taken by EPA in its nation wide measurement program were at the Mt. Wilson, CA antenna farm.

94. Vol. 44 Federal Register at 38916.

95. Department of Commerce, "Charter of the Electromagnetic Radiation Management Advisory Council" (December 29, 1978)

Chapter VII

CONCLUSION

From the foregoing it is apparent that some form of regulatory control over RFR emissions is required. It does appear that we have not yet reached a point where the health of the public at large has been placed in jeapordy by RFR emissions. However we appear to be fast approaching the point in time (if not already there) where the federal government needs to interceed to ensure the health of those who work around RFR emitters and members of the public who reside near major emitters.

We are not yet to the point where we can accuratly predict any but the most obvious effects of RFR with any form of unanimity among the scientific community. But the information appears to be growing at a rapid pace. Not all of the more recent scientific findings help. Some raise more questions than they answer. The work of Adey finding biological effects in brain tissue has been replicated and may show evidence of heretofore unknown interactions between RF energy and the body's neurological system.

But findings such as this raise questions such as how these interactions translate into potential adverse health effects, and if there is a potential for adverse health effects, why have we not yet seen them in living creatures? Is it because these clinically observed effects do not directly manifest themselves into adverse biological effects? Or perhaps is it that we don't yet understand enough about RFR and its interactions with the body to know what to look for?

Taking for granted that RFR can cause adverse biological effects at some time-intensity level, should it be regulated and if so,by whom?

RFR as a form of energy has unique characteristics that make it somewhat different to deal with as opposed to the traditional pollutants which are invariably matter in one form or another. An overview of the biological research indicates that frequency (i.e. type of RFR) and the energy level (measured in some instances for both the magnetic and electrical properties of the RFR and representing the volume of RFR) are two key characteristics. Other important factors include the receptor of the RFR. Particularly important here is use of SAR to provide a common denominator for many important variables involving the biologic receptor of the RFR energy. These variables include the problems in reconciling test results upon different sized receptors. Also important is the environment surrounding the receptor. Is the receptor grounded, shielded from the RFR or placed so that it, he or she will receive additional RFR

energy due to reflections?

Taken together these factors tend to indicate there are few generalities about RFR as an environmental or occupational pollutant. Rather the potential hazard, if any, presented by the RFR appears to be largely specific as to site and/or circumstance. As such this would seemingly call for a form of site specific or point source control. Such an avenue for point source control already exists, as has been discussed, through the FCC's licensing program. Every civilian emitter, either individually or as a class must be approved at some point in time by the FCC as part of their duties to regulate the frequency spectrum. The aspects of the emitters they review are also the key aspects of RFR from a bio-effects standpoint: frequency, energy output, and often siting.

It would seem logical then that a review for potential adverse RFR biological effects should be tied to the FCC licensing procedure, rather than creating an independent "pollution control authority". It would not be necessary that the FCC develop the in-house expertise to implement such a program. Rather the responsibility could be shared with another agency with technical expertise in the bio-effects area. An arangement similar to this already exists in the FCC's granting of broadcast licenses to emitters with towers of such height that they may present a hazard to aircraft[2]. In these instances the broadcast applications are referred to the FAA which exercises its expertise in the area of air safety to determine whether the tower as proposed may present a risk to aviation safety.

What federal agency could take the place of the FAA in the area of assessing potentially harmful RFR bio-effects is albeit somewhat difficult to discern. OSHA, no doubt has the statutory authority to fill that role for emitters to be sited in the workplace. Seemingly BRH has a similar authority under the RCH&S Act to regulate emissions from "electronic products." However BRH working in conjunction with the FCC appears outside the intent of the RCH&S Act. Absent a statutory amendment clearly establishing such a role, There appears a potential that the NEPA process could be used[3]. This however would require the co-operation of both the BRH in commenting on FCC environmental documents and the FCC's co-operation in listening to BRH's comments and making decisions based on those comments. Whether this will take place in the near term remains doubtful considering the FCC's current version of NEPA implementing regulations which ignore the environmental issue of non-ionizing radiation[4].

As for emitters in the federal sector these could readily be controled if EPA issues its RFR guidance through the mechanism of a Presidential order as currently proposed.

While there appear to be mechanisms to achieve a framework to control RFR, at this time those agencies which have the authority to issue controlling regulations (i.e. BRH, FCC, OSHA) appear unwilling to do so.

The only agency that has recently evidenced a willingness to regulate, appears to lack the statutory authority to regulate the large number of private emitters of concern.

FOOTNOTES

1. In the RFR area, it would seem that regulation would better be done at the national as opposed to the state or local level (albeit, admittedly, the thrust of the Atomic Energy Act of 1954 is to place increased regulatory control in the hands of state and local agencies).

Use of the RFR spectrum is somewhat unique. The spectrum offers great benefits to the public in the areas of public service and public safety. But the RFR spectrum, and its forms of broadcast uses do not normally recognize man-made geographical limitations such as state and local boundaries. Seemingly for the spectrum to be used efficiently (and for the related industries to be profitable), emitters and their uses should not be limited by artificial man-made geographical limits on technology.

This recognition apparently led to the split in industry responses to the FCC's notice of inquiry, (supra, Chapter VI, note 81). The responses fell into two catagories. The first set represented the typical "knee jerk" responses seeking to keep the FCC out of the business of regulating RFR for its environmental effects (and hence attempting to hold off any attempt to regulate RFR radiation). The second catatory (and the more progressive view in the mind of this author) were those responses noting that a nationwide scheme for RFR regulation would be preferable in comparison to a plethora of different regulations promulgated by a variety of state and local jurisdictions.

Industry representatives advocating this view invariably mentioned the then recent effort by New York City to pass a local regulation limiting RFR emissions to 50 uW/cm^2 (0.05 mW/cm^2). This attempt appeared driven by public psychosis over possible RFR effects rather than technically valid biological concerns.

2. 47 C.F.R. Part 17.

3. The U.S. Air Force's Systems Command is charged with developing and fielding that service's major RFR emitters (radar and communications devices). They have taken to thoroughly documenting RFR power levels and potential effects in their environmental assessments and environmental impact statements. As a general practice that organization has taken to including isopleths in their environmental documents denoting the areas around emitters which may be affected by RFR and the energy levels expected in those areas.

4. One instance reported at the July, 1981 meeting of the ERMAC points up the overall lack of concern by many agencies

for potential RFR bio-effects. In this case a broadcast tower was installed in a public parking lot with cars (recall the high instance of reflectivity in autos from the discussion of mobile radios) being allowed to park and drive with in scant feet of the base of the tower. As discussed at the meeting, the EPA's general concept of RFR control would have likely required a large exclusion fence prohibiting public access near the base of the tower.

Chapter VIII

Appendix

The Electromagnetic Spectrum

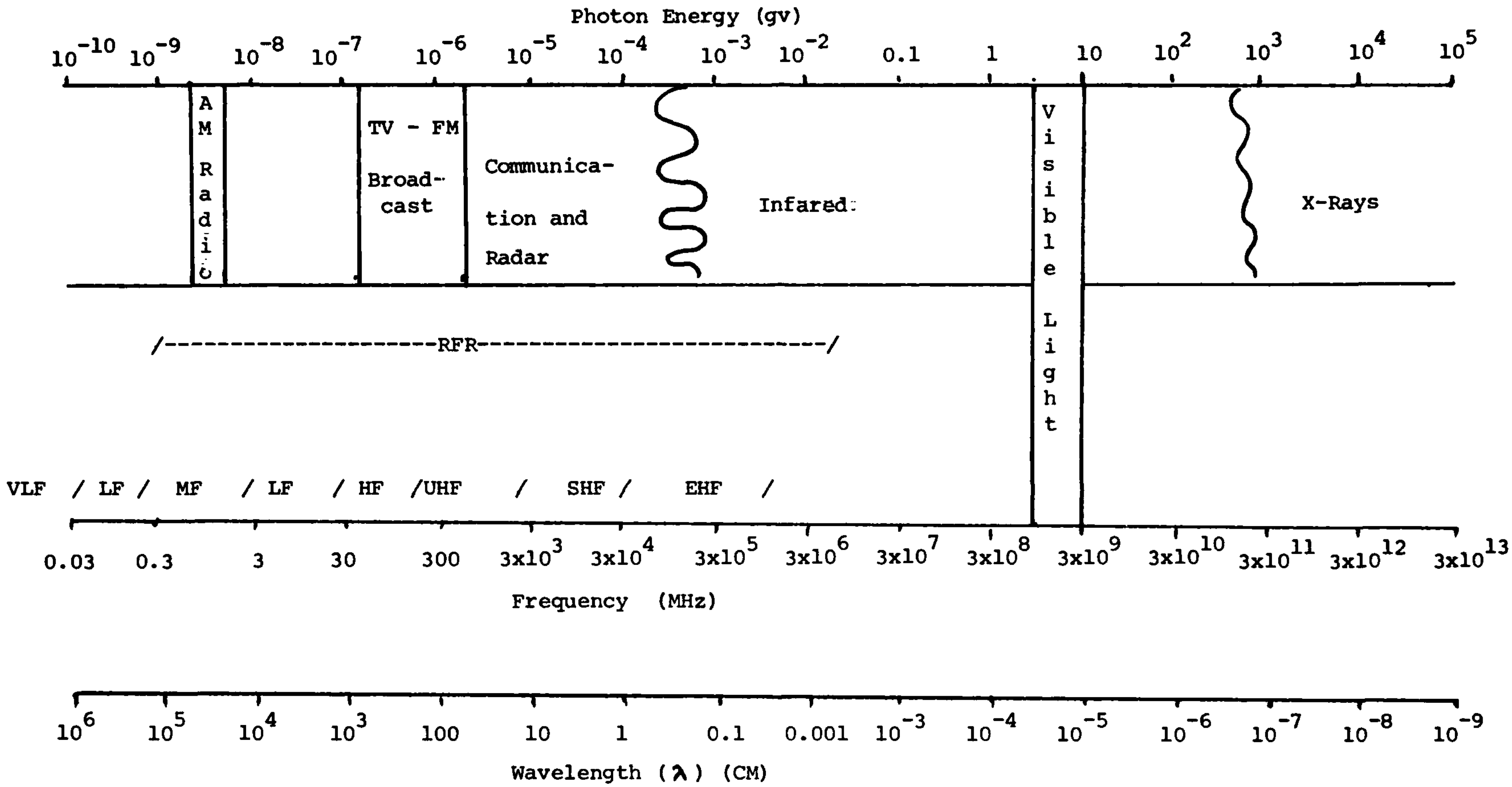


Figure 1

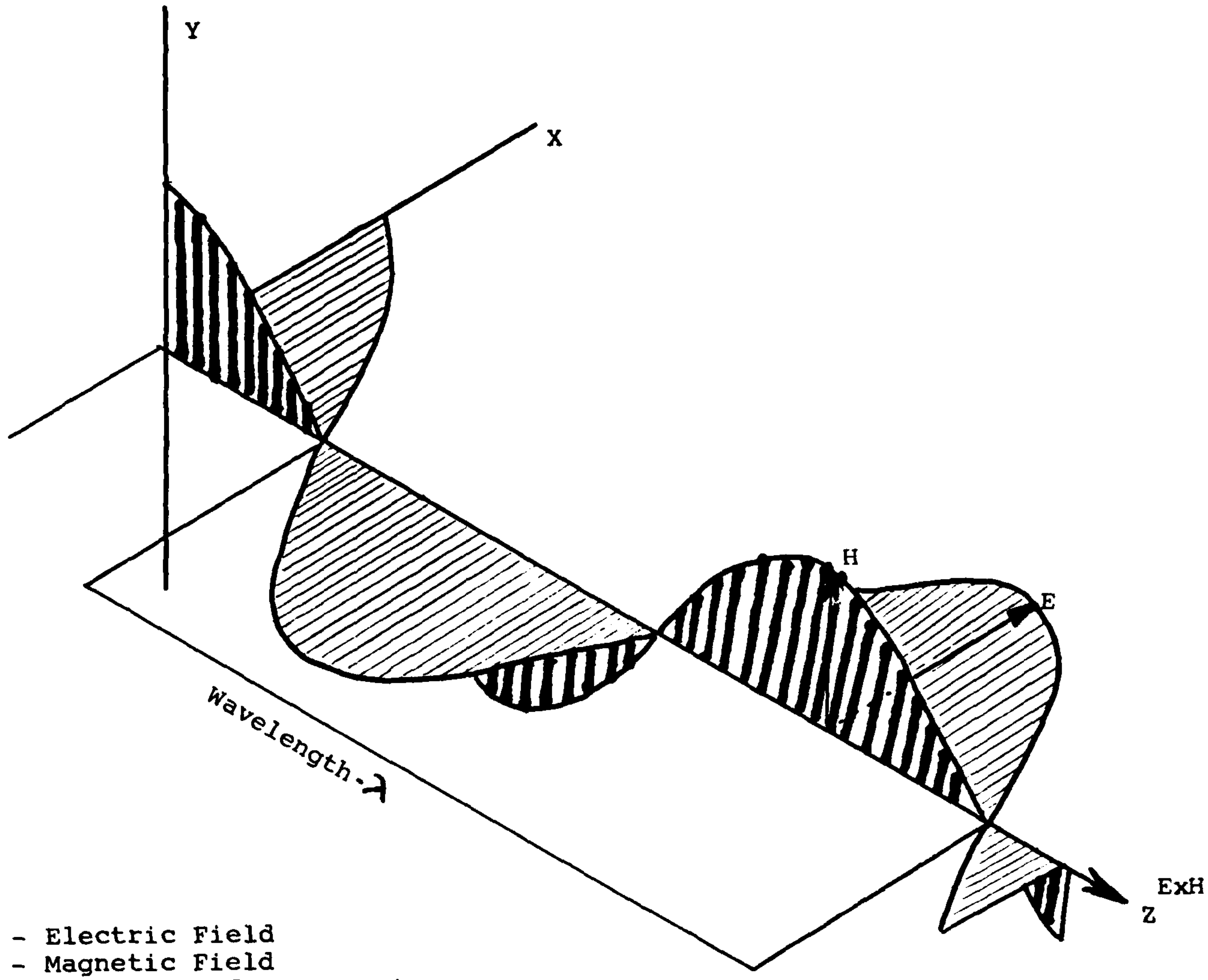
Radio frequency and microwaves.

Approximate wavelength in air (meter)	Frequency MHZ
15.10^3 and more	0.02 and less
10^4	0.03
$3 \cdot 10^3$	0.1
1000	0.3
800	0.4
100	3
30	10
10	30
1.5	200
10^{-1}	300
10^{-3}	3,000
10^{-3}	30,000
$1.5 \cdot 10^3$	200,000
10^{-3}	300,000
$0.75 \cdot 10^{-3}$	400,000
$0.2 \cdot 10^{-3}$	1,000,000

DESIGNATIONS

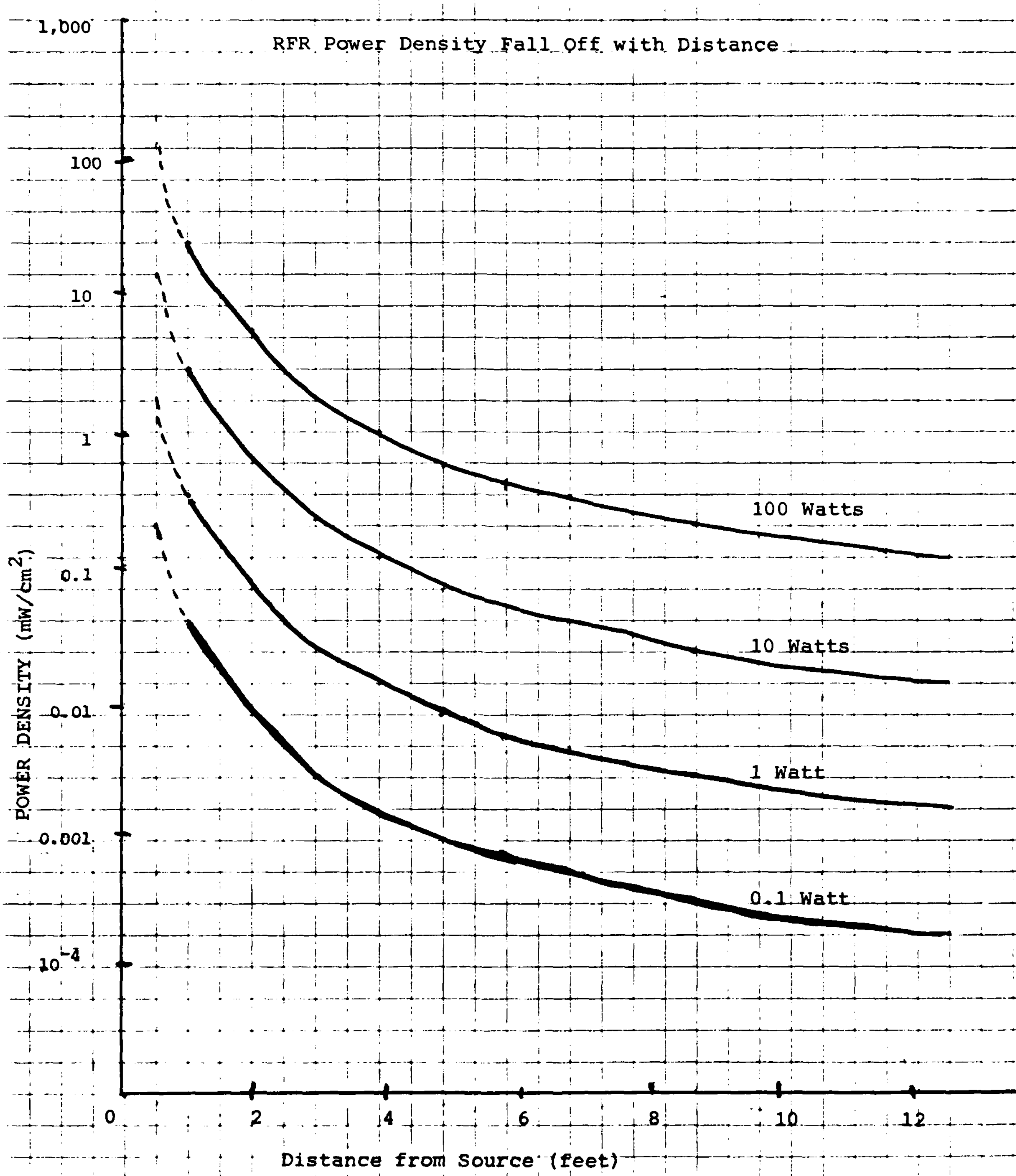
Russian literature	Metric, used in USSR, Poland, and Czechoslovakia	English and American literature	Loosely used
low frequency	Dekamyria and myriameter waves	VLF, very low frequency	AF, audio frequency
		LF, low frequency	
	Kilometer waves		
high frequency		MF, median frequency	RF, radio frequency Hertzian waves
	Hektometer waves		
	Dekameter waves	HF, high frequency	
ultrahigh frequency	Meter waves		
superhigh frequency	Decimeter waves Centimeter waves	UHF, ultra frequency SHF, super high frequency	Designated as microwaves, radar emanations, UHF, or HF
	Millimeter waves	EHF, extra high frequnecy	
infra	IR	IR	IR

Figure 2



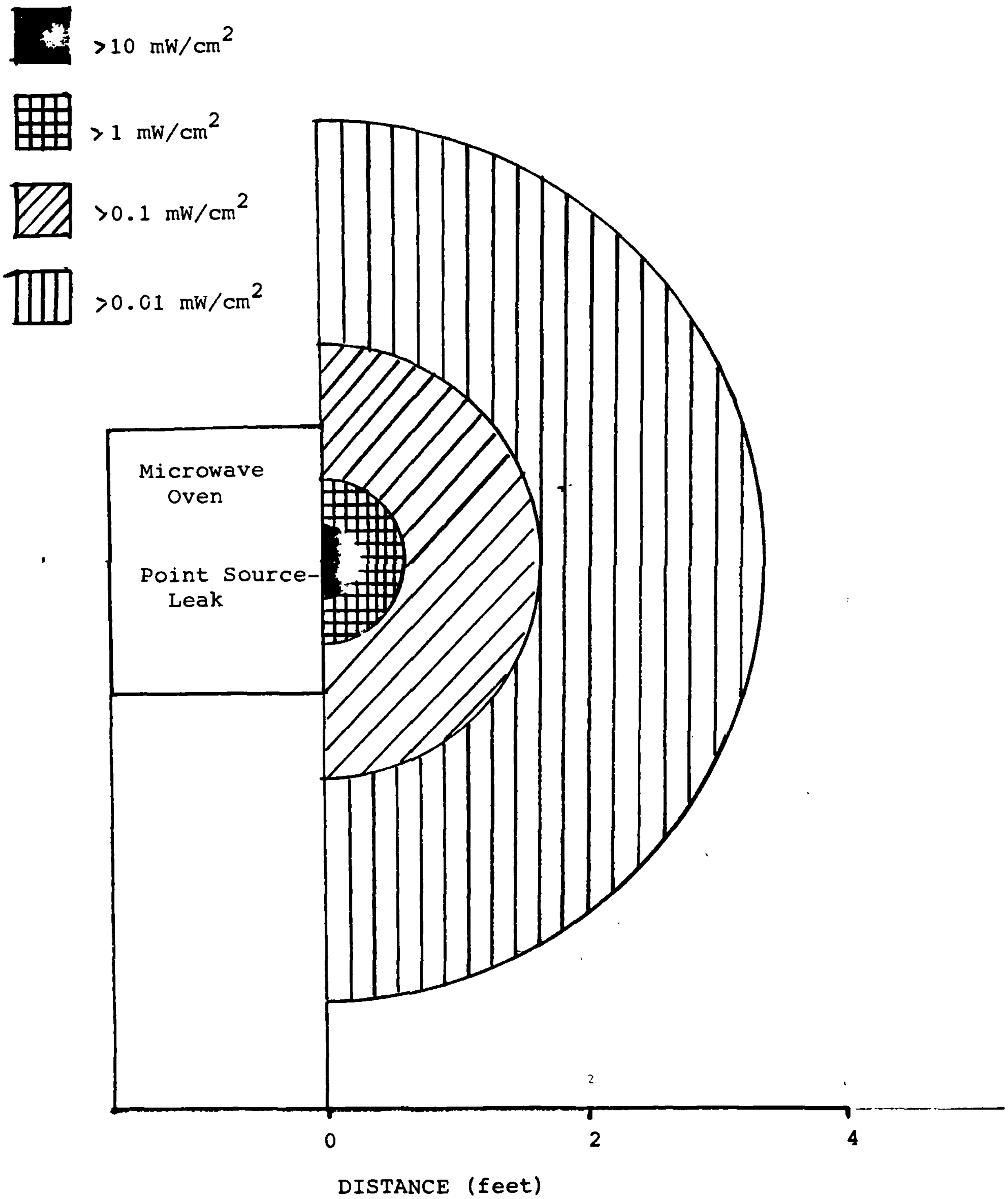
E - Electric Field
H - Magnetic Field
Z - Direction of Propagation

FIGURE 3



RFR Power Density Fall Off with Distance
1,000
100
10
1
0.1
0.01
0.001
10^{-4}
POWER DENSITY (mW/cm^2)
100 Watts
10 Watts
1 Watt
0.1 Watt
0
2
4
6
8
10
12
Distance from Source (feet)

Figure 4



>10 mW/cm2
>1 mW/cm2
>0.1 mW/cm2
>0.01 mW/cm2
Microwave Oven
Point Source-Leak
0
2
4
DISTANCE (feet)

Figure 5

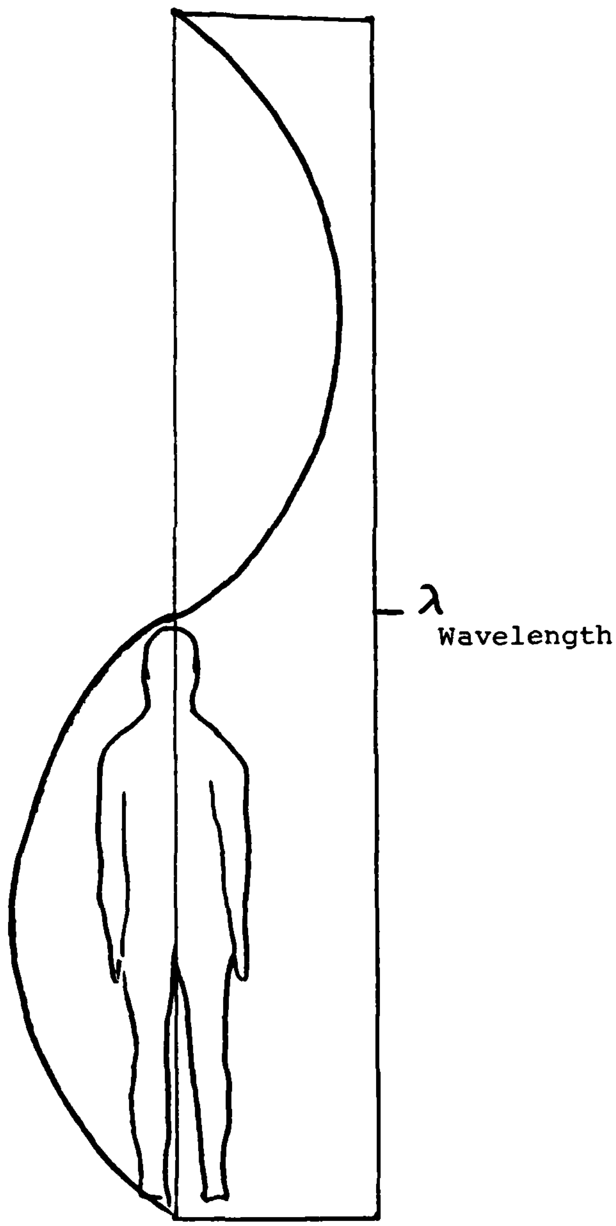
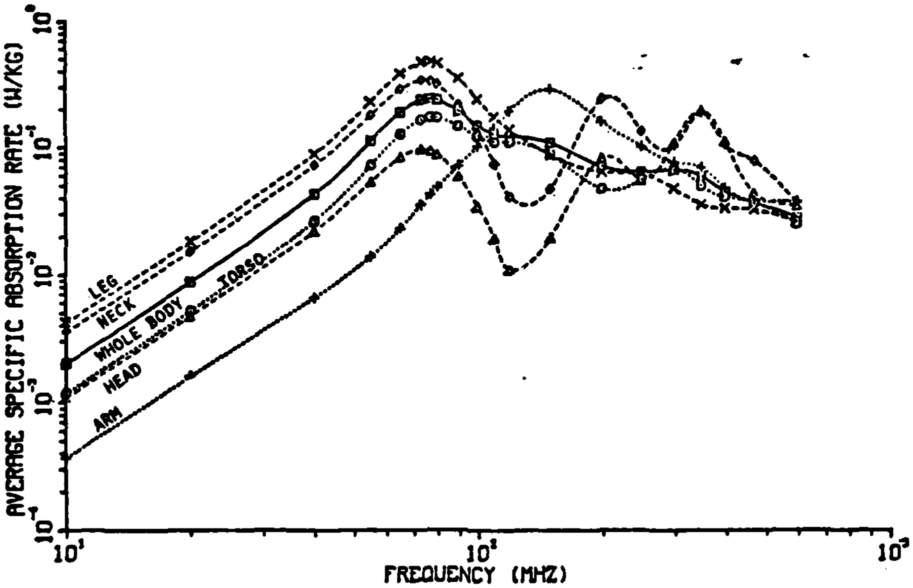


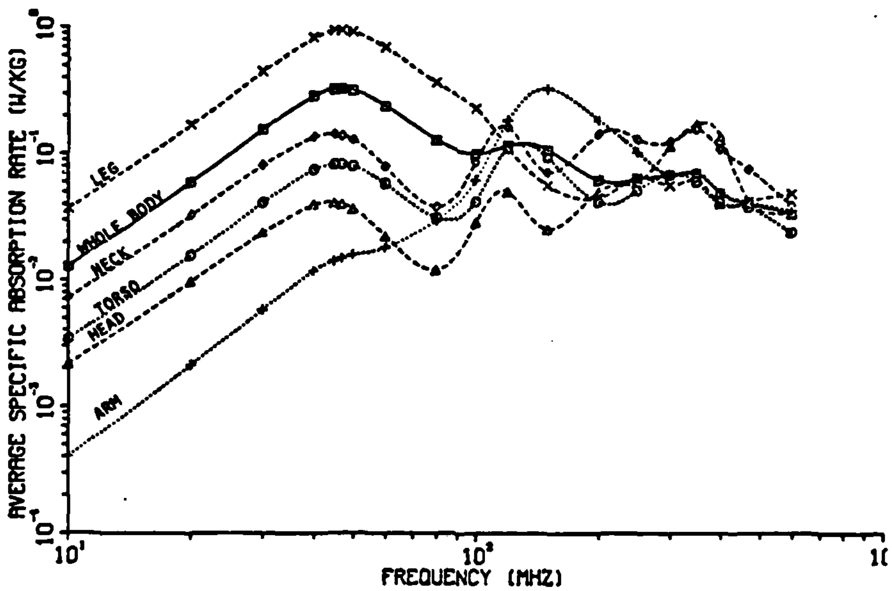
Figure 6



Specific absorption rates for the whole body an some intact anatomical parts of man in W/kg for a free space incident power density of 1mW/cm^2

(taken from Tell, Technical Note "An Analysis of Radio Frequency and Microwave Absorption Data with Consideration of Thermal Safety Standards," (1978))

Figure 7



Specific absorption rates for the whole body and some intact anatomical parts of man in W/kg for an incident power density of $1 mW/cm^2$ when man is in good electrical contact with a high conductivity ground plane.

(taken from Tell, Technical Note " An Analysis of Radio Frequency and Microwave Absorption Data with Consideration of Thermal Safety Standards," USEPA, (1978))

Figure 8

Figure 9

Power Deposition for a Human Form under Free Space Irradiation

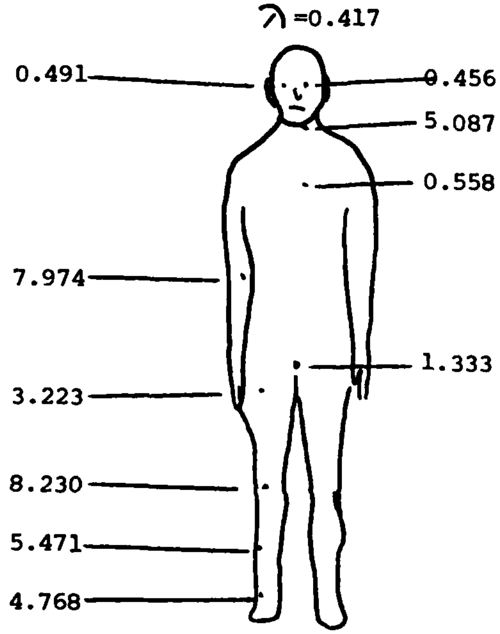
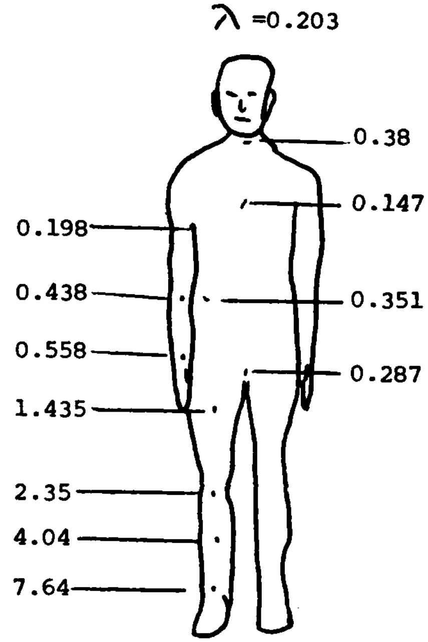
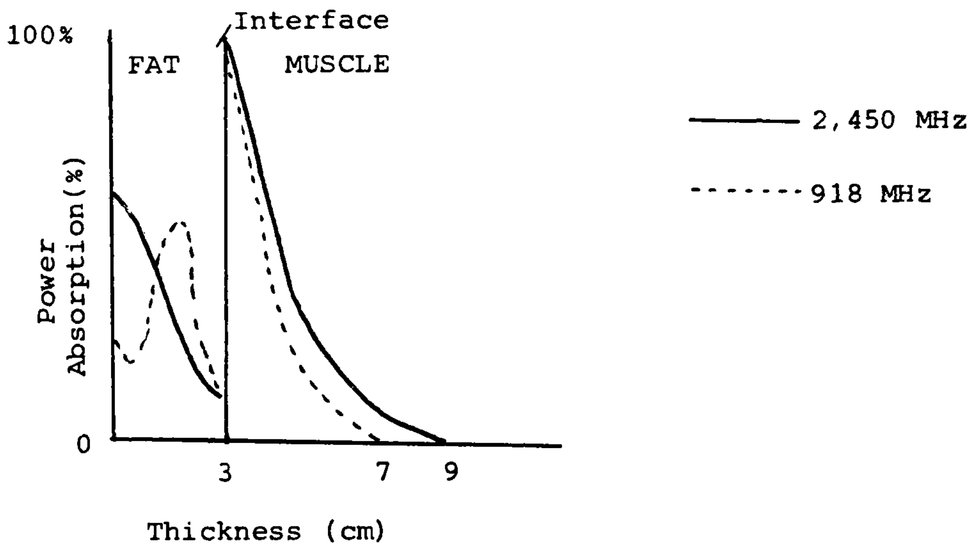


Figure 10

Power Deposition for a Human Form with Feet in Electrical Contact with Ground



Numbers relate to the whole body average SAR of 4.5 W/kg for a 1.75m tall man exposed to $10 mW/cm^2$ RFR field.



Relative absorbed power density in two plane layers (fat/muscle) illuminated by a plane wave. Note the discontinuity at the interface and the difference in absorption rate between the frequencies.

Figure 11

Probable Mechanisms of Microwave Interaction

(adapted from Baranski and Czerski)

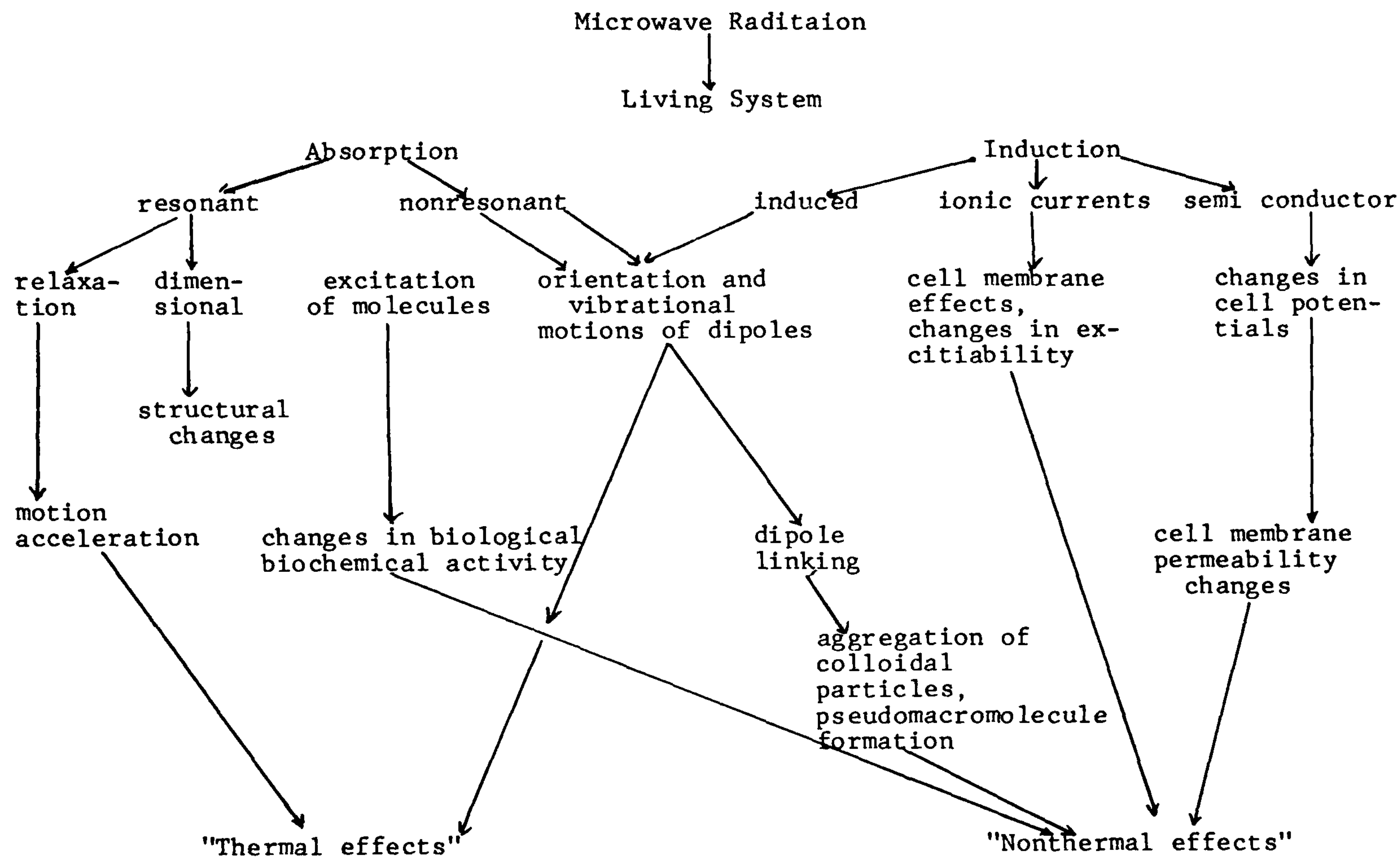


Figure 12

Outline of Possible Mechanisms for RFR Interaction with Living Systems
(adapted from Baranski and Czerski)

I. Molecular Level:

- **A. Primary Effects**: Primary heating effects on mono-and poly-H_2O segmental rotation of biopolymers, conformation changes in biopolymers, excitation of molecular, ionic currents and changes in ion distribution
- **B. Secondary Chain of Events**: Temperature rises--metabolic rate effects on biochemical reactions through conformation changes, excitation, changes in ion distribution, structural changes in subcellular elements (chromosomes,mitochondria, membranes)

II. Subcellular and Cellular Levels:

- **A. Primary Effects**: Interference with biomembranes (or secondary effects through ionic currents and changes in ion distribution), semiconductor effects, changes in bound water
- **B. Secondary Chain of Events**: Chromosomal effects, lymphoblastoid transformation, interference with mitosis, genetic effects, carcinogenic effects

III. Organs and Systems:

- **A. Primary Effects**: Focal thermal stimulation and/or lesions
- **B. Secondary Chain of Events**: Cardiovascular local and/or generalized effects, nervous system by peripheral receptor stimulation and "disorganization" of function (focal lesions or stimulation), same for endocrine system, effects of changes in metabolic rate, and/or abnormal metaboloties

IV. Highly Organized Living Systems:

- **A. Primary Effects**: Interference with electromagnetic wave transmission and/or reception of biological information
- **B. Secondary Chain of Events**: Stress effects (cumulation ofchronic microtrauma and microstress), adaptive responses, desadaptation, interference with biorhythms and their sychronization

(**NOTE**: The foregoing represents Baranski and Czerski's concepts on possible mechanisms by which RFR might react with biologic entities and how these mechanisims might manifest themselves in secondary effects. Recent research makes doubtful several of the mechanisms postulated above. However, the table is still illustrative of the need to consider the several biological levels at which RFR might react with biologic entities)

Figure 13

BIO-EFFECTS LITERATURE
ANSI C95.4 COMMITTEE MEETING
UNIVERSITY OF WASHINGTON
FEBRUARY 28 - MARCH 2, 1979

1. Environmental Factors

a. Shandala, M.G., M.I. Rudnev, and M.A. Navakatian, Patterns of change in behavioral reactions to low power densities of microwaves. In Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves, Airlie, VA, Oct. 30-Nov. 4, p. 88.

b. Johnson, R.B., S. Mizumori, R.H. Lovely, and A.W. Guy, Adaptations to microwave exposure as a function of power density and ambient temperature in the rat. In Abstracts of 1978 Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, June 27-30, p. 30.

c. Monahan, J.C. and H.S. Ho, Microwave induced avoidance behavior in the mouse. In Biological Effects of Electromagnetic Waves, C.C. Johnson and M.L. Shore, editors, HEW Publication (FDA) 77-8010, Vol. I, 274-283, 1976.

2. Behavior and Physiology

a. D'Andrea, L.A., O.P. Gandhi, and J.L. Lords, Behavioral and thermal effects of microwave radiation at resonant and nonresonant wavelengths. Radio Science, 12 (6S), 251-256, 1977.

b. Thomas, J.R., E.D. Finch, D.W. Fulk, and L.S. Burch, Effects of low-level microwave radiation on behavioral baselines. Annals of the New York Academy of Sciences, 247, 425-431, 1975.

c. Frey, A.H., Behavioral effects of electromagnetic energy. In Biological Effects and Measurement of Radio Frequency/Microwaves, D.G. Hazzard, editor, HEW Publication (FDA) 77-8026, 11-22, 1977.

d. King, N.W., D.R. Justesen, and R.L. Clarke, Behavioral Sensitivity to Microwave Irradiation. Science, 172, 398-401, 1971.

e. Frey, A.H., S.R. Feld, and B. Frey, Neural function and behavior: Defining the relationship. Annals of the New York Academy of Sciences, 247, 433-438, 1975.

f. Lin, J.C., A.W. Guy, and L.R. Caldwell, Thermographic and behavioral studies of rats in the near field of 918-MHz radiation. IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-25 (10), 833-836, 1977.

Figure 14

3. Immunology

a. Shandala, M.G., M.I. Rudnev, G.K. Vinogradov, N.G. Belonozhiko, and N.M. Gonchar, Immunological and hematological effects of microwaves at low power densities. In Abstracts of 1977 International Symposium on the Biological Effects of Electromagnetic Waves, Airlie, VA, Oct. 30-Nov. 4, p. 85.

b. Czerski, P., Microwave effects on the blood-forming system with particular reference to the lymphocyte. Annals of the New York Academy of Sciences, 247, 232-241, 1975.

c. Huang, A.T., M.E. Engle, J.A. Elder, J.B. Kinn, and T.R. Ward. The effects of microwave radiation (2450 MHz) on the morphology and chromosomes of lymphocytes. Radio Science 12 (6S), 173-177, 1977.

d. Smialowiz, R.J., J.B. Kinn, and J.A. Elder, Exposure of rats in utero through early life to 2450 MHz (CW) microwave radiation: Effects on lymphocytes. Radio Science 14/S, 1979, in press.

e. Smialowiz, R.J., C.M. Weil, J.B. Kinn, and J.A. Elder, Exposure of rats to 425 (CW) microwave radiation: Effects on lymphocytes. Journal of Microwave Power, in press.

4. Teratology

a. Berman, E., J.B. Kinn, and H.B. Carter. Observations of mouse fetuses after irradiation with 2.45 GHz microwaves. Health Physics 35, 791-801, 1978.

5. Central Nervous System/Blood-Brain-Barrier

a. Bawin, S.M., L.K. Kaymarck, and W.R. Adey, Effects of modulated VHF fields on the central nervous system. Annals of the New York Academy of Sciences 247, 74-80, 1975.

b. Blackman, C.F., J.A. Elder, C.M. Weil, S.G. Boname, D.C. Eichinger, and D.E. House. Induction of calcium in efflux from brain tissue by radio-frequency radiation: Effects of modulation-frequency and field-strength. Radio Science 14/S, 1979, in press.

c. Frey, A.H., S.R. Feld, and B. Frey, Neural function and behavior: Defining the relationship. Annals of the New York Academy of Sciences, 247, 433-438, 1975.

d. Albert, E.N., Light and electron microscope observations on the blood-brain barrier after microwave irradiation. In Biological Effects and Measurement of Radio Frequency/Microwaves, D.G. Hazzard, editor, HEW Publication (FDA) 77-8026, 294-304, 1977.

6. Cataracts: None $\leq$ 10 mW/cm^2

7. Genetics: None $\leq$ 10 mW/cm^2

8. Human Studies: None

9. Thermoregulation and Metabolism

   a. Lovely, R.H., D.E. Myers, and A.W. Guy, Irradiation of rats by 918 MHz microwaves at 2.5 mW/cm^2: Delineating the dose-response relationship. Radio Science 12 (6S), 139-146, 1977.

   b. Stern, S., L. Margolin, B. Weiss, and S.-T. Lu, Microwaves affect thermoregulatory behavior in rats. Abstract, Bioelectromagnetics Symposium, Seattle, WA, June 18-22, 1979.

   c. Adair, E.R., Microwave modification of thermoregulatory behavior: Threshold and suprathreshold effects. Abstract, Bioelectromagnetics Symposium, Seattle, WA, June 18-22, 1979.

   d. De Lorge, J.O., Operant behavior and colonic temperature of squirrel monkeys (*Saimiri sciureus*) during microwave irradiation. NTIS Document No. AD A043706, 33 pp., 1977.

   e. Lu, S.-T., N. Lebda, and S.M. Michaelson, Effects of microwave radiation on the rats' pituitary-thyroid axis. Radio Science 14/S, 1979, in press.

10. Biorhythms

    a. Lu, S.-T., N. Lebda, and S.M. Michaelson, Effects of microwave radiation on the rats' pituitary-thyroid axis. Radio Science 14/S, 1979, in press.

11. Endocrinology

    a. Lovely, R.H., A.W. Guy, R.B. Johnson, and M. Mathews, Alterations of behavioral and biochemical parameters during and consequent to 500 uW/cm^2 chronic 2450 MHz microwave exposure. In Abstracts of 1978 Symposium on Electromagnetic Fields in Biological Systems, Ottawa, Canada, June 27-30, p. 34.

    b. Travers, W.D., Low intensity microwave effects on the synthesis of thyroid hormones and serum proteins, Health Physics 33(6), 662, 1978.

12. Development

    a. Michaelson, S.M., R. Guillet, and F.W. Heggeness, The influence of microwaves on development of the rat. Radio Science 14/S, 1979, in press.

b. McRee, D.I. and P.E. Hamrick, Exposures of Japanese quail embryos to 2.45 GHz microwave radiation during development. Radiation Research 71(2), 355-366, 1977.

c. Johnson, R.B., S. Mizumori, and R.H. Lovely, Adult behavioral deficit in rats exposed prenatally to 918 MHz microwaves. In Developmental Toxicology of Energy Related Pollutants, M. Sikov and D. Malum, editors, 17th Hanford Symposium, DOE, GPO, pp. 281-299. 1979.

13. RF Hearing

14. Hematology

a. Mitchell, D.S., W.G. Switzer, and E.L. Bronaugh, Hyperactivity and disruption of operant behavior in rats after multiple exposures to microwave radiation. Radio Science 12 (6S), 263-271, 1977.

b. Miro, L., R. Loubiere, and A. Pfister, Effects of microwaves on the cell metabolism of the reticulo-historytic system. In Biologic Effects and Health Hazards of Microwave Radiation, P. Czerski, K. Ostrowski, M.L. Shore, C. Silverman, M.J. Suess and B Weldeskoz, editors, Polish Medical Publishers, Warsaw, pp. 89-97, 1974.

15. Cardiovascular

a. Reed, J.R., J.L. Lords, and C.H. Durney, Microwave irradiations of the isolated rat heart after treatment with ANS blocking agents. Radio Science 12 (6S), 161-165, 1977.

CALCULATION OF SAR IN ANIMALS USED TO OBTAIN RESEARCH RESULTS SELECTED BY ANSI C95.4 SUBCOMMITTEE

RESEARCH PAPER	SUBJECT & SIZE	ORIENTATION WITH E FIELD	FREQUENCY (GHz)	SAR PER mW/cm^2	MODULATION	AVG. POWER DENSITY mW/cm^2	PEAK POWER DENSITY mW/cm^2	DURATION OF EXPOSURE	AVG. SAR W/kg
M. Shandala, et al. 1a	Rats (310 g)	---	2.375	0.21 (med. rat)	CW	10-50	---	7 hrs/day 90 days	.0021-.0105
B. Johnson, et al. 1b	Rat embryo in mother (448 g)	---	.918	0.30 (large rat)	CW	5	---	100 hours	1.5
Ho and Monahan 1c	Mouse (30-34 g)	---	2.45	waveguide SAR measured by author	CW		---		9.0 @ 35 °C
D'Andrea, et al. 2a	Rat (420-450 g)	Long axis // to E	.600	0.61 (large rat)	CW	10	---	---	6.1
Thomas, et al. 2b	Rat	?	2.86 and 9.6	0.20 - 0.16	Pulse	5	?	1 hour	1.0 Far Field 0.8
Frey 2c	Rat (250 g)	Horizontal	1.3	0.36 (med. rat)	0.5 ms wide 1000 pps	.65	1.3 mW/cm^2	---	Avg: 0.23 Peak: 0.47
King, et al. 2d	Rat (400 g)	Cavity	2.45	0.22 (med. rat)	CW		---	<60 sec.	0.6 W/kg
Frey, et al. 2e	Rat (med.)	?	1.2	0.36	Pulsed and CW	.2	2.1 mW/cm^2 2.4 mW/cm^2	--- ---	Avg: .07 Peak: .076 0.86
M. Shandala, et al. 3a	Rat (med.)		2.375	0.21	CW	10^{-2}	---	90 days	.0021
Czerski, P. 3b	Mouse (20 g)	Group Exp. Far Field	2.950	1.1	1 us 1200 pps	0.5	---	6-12 wks	0.55
Huang, et al. 3c	Hamster (35g)	Dorsal Group Exp. Far Field	2.45	1.1	CW	5	---	15 min/day for 5 days	5.5
Smialowicz, et al. 3d	Neonatal Rats (50-90g)	Dorsal Individual	2.45	0.7-4.7	CW	5		60 days	0.7-4.7
Smialowicz, et al. 3e	Rats (8-180g)	Crawford Cell	.425	measured by author	CW	10	---	40 days	4

CALCULATION OF SAR IN ANIMALS USED TO OBTAIN RESEARCH RESULTS SELECTED BY ANSI C95.4 SUBCOMMITTEE

RESEARCH PAPER		SUBJECT & SIZE	ORIENTATION WITH E FIELD	FREQUENCY (MHz)	SAR PER mW/cm^2	MODULATION	AVG. POWER DENSITY mW/cm^2	PEAK POWER DENSITY mW/cm^2	DURATION OF EXPOSURE	AVG SAR W/kg
Berman, et al.	4a	Mice (25-33g)	Dorsal Multiple	2450	0.8	CW	28		100 min/day for 1-17 d	22.2
Bawin, et al.	5a	Chick Brain	Parallel plate in vitro	147		AM (0.5-32 Hz)	<1		20 min	0.003
Blackman, et al.	5b	Chick Brain	Crawford cell in vitro	147		AM (0, 3, 9, 16, 30 Hz)	0.75		20 min	0.0023
Frey, et al.	5c	Rats (225g)	Head positions varied	1200	0.30	P	0.2	2.1	30 min	0.06
						CW	2.4		30 min	0.72
Albert, E.	5d	Chinese Hamsters (≈35g)	---	2450	1.0	CW	10		2 or 8 hr for 1 day	10
Lovely, et al.	9a	Rats (316-388g)	Waveguide	918	0.36	CW	2.5		1 hr/day for 13 wks	0.9
Stearn, et al.	9b	Rats (325-400g)	Dorsal	2450	0.18	CW	5		15 min intermittent	0.9
Adair, E.	9c	Squirrel monkey (.1 kg)	---	2450	0.13	CW	6		15 min intermittent for 3 hrs	0.78
DeLorge, E.	9d	Squirrel monkey		2450	0.13	AM (120 Hz)	50 mW/cm^2		30-60 min	6.5
Lu, et al.	9e, 10a	Rat (150g)		2450	0.36	CW	1 mW/cm^2		8 hr	0.36
Lovely, et al.	11a	Rats (300-350g)		2450	0.21	CW	0.5		7 hrs/day for 3 mo.	0.11
Travers, W.	11b	Rat		2450	0.21	CW	8		8 hrs/day 0, 7, 14 or 21 days	1.68
Michaelson, et al.	12a	Rats (neonatal) (10-25g)		2450	1.3	CW	10		1 hr	13
McRee, et al.	12b	Japanese quail embryo (10g)		2450	0.8	CW	5		12 days	4
Johnson, et al.	12c	Rats (200-300g)	Waveguide	918	0.5	CW	5		20 hrs/day for 19 days	2.5
Mitchell, et al.	14a	Rats (307g)	15/group cavity	2450	0.5	CW	2.3		1 hr & 5 hr/d 110 days	1.2
Miro, et al.	14b	Large mouse (26-30g)	Horizontal	3105		Pulsed 5 Hz-1ms	2 mW/cm^2		145 hr	1.8
Reed, et al	15a	Isolated rat heart		960		CW			10 m	1.5

AVERAGE WHOLE BODY SAR CORRESPONDING TO BIOLOGICAL EFFECTS REPORTED IN VARIOUS REFERENCES

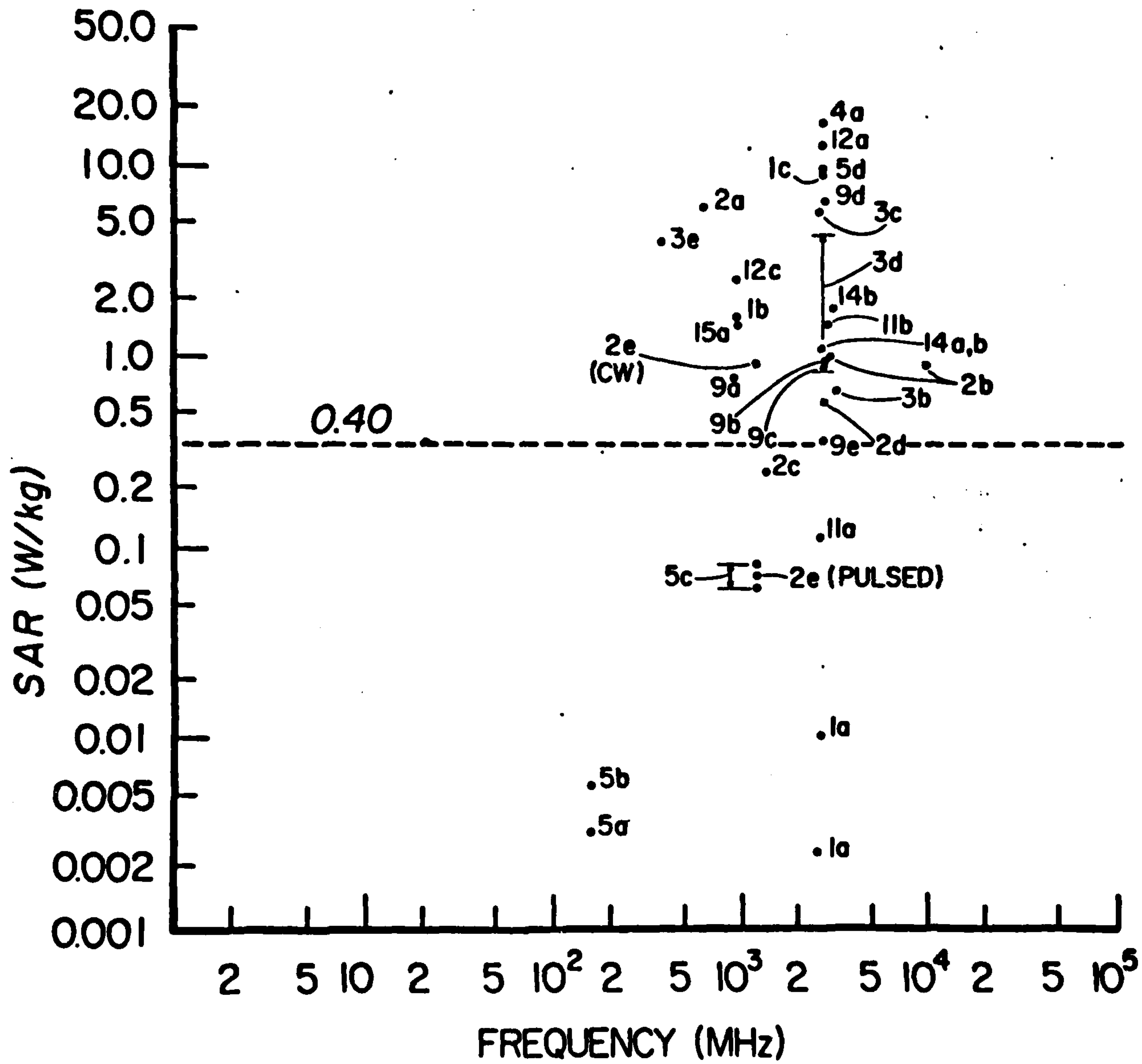


Figure 15

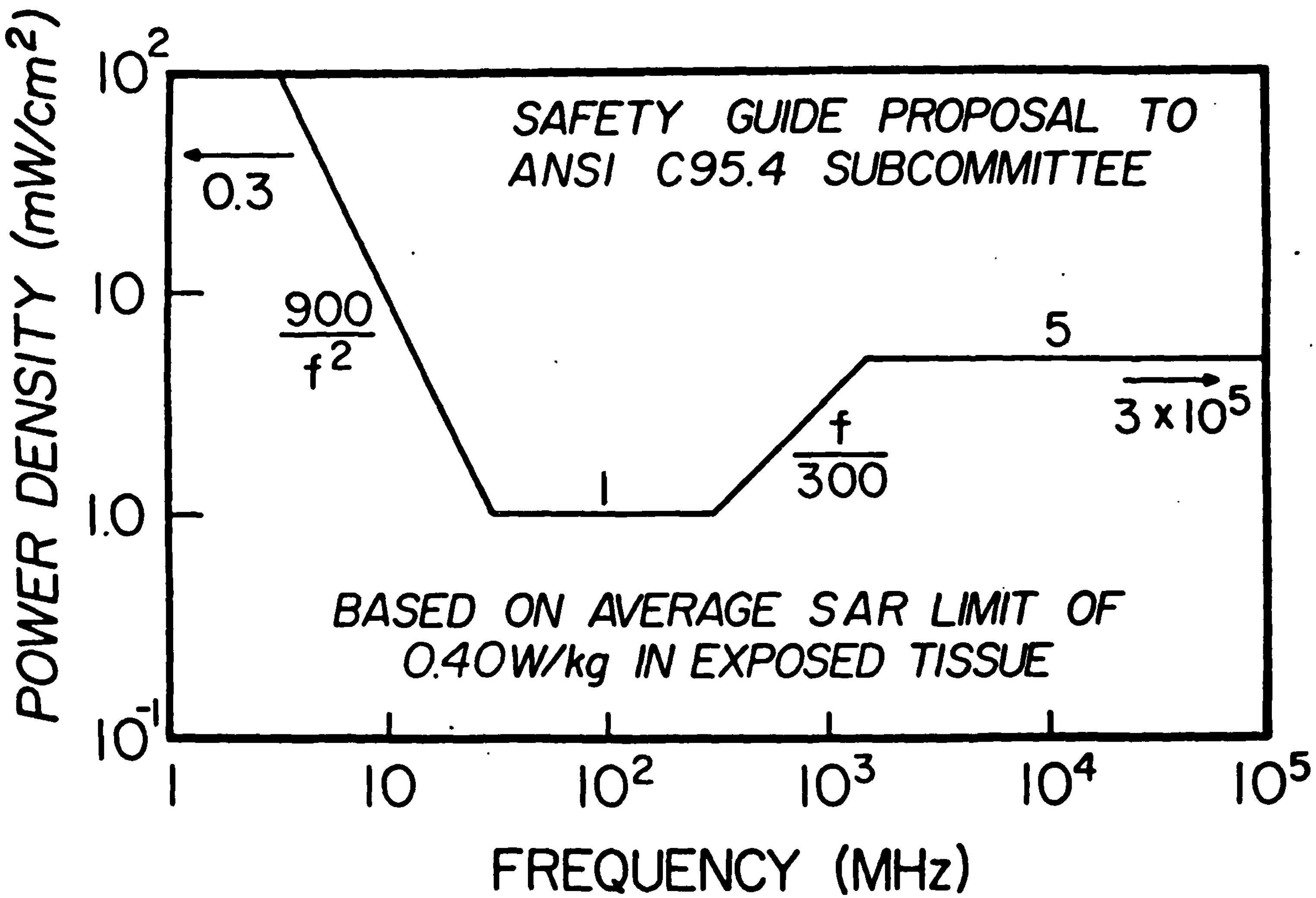

SAFETY GUIDE PROPOSAL TO
ANSI C95.4 SUBCOMMITTEE
BASED ON AVERAGE SAR LIMIT OF
0.40W/kg IN EXPOSED TISSUE
POWER DENSITY (mW/cm²)
FREQUENCY (MHz)
0.3
900/f²
1
f/300
5
3 x 10⁵
10²
10
1.0
10⁻¹
1
10
10²
10³
10⁴
10⁵

Figure 16

TABLE 1

Frequency MHz	Wavelength air/tissue (cm)	Dielectric constant	Depth of penetration (cm)
100	300/27	71.7	6.66
200	150/16.6	56.5	4.79
300	100/11.0	54	3.89
433	69.3/8.76	53	3.57
750	40/5.34	52	3.18
915	32.8/4.46	51	3.04
1,500	20/2.81	49	2.42
2,450	12.2/1.76	47	1.70
3,000	10/1.45	46	1.61
5,000	6/0.89	44	0.788
5,800	5.17/0775	43.3	0.720
8,000	3.75/0.578	40	0.413
10,000	3/0.464	39.9	0.343

Characteristics of electromagnectic wave propagation in high water content tissue (e.g. muscle and skin) at various frequencies. Adapted from Baranski and Czerski at 50.

TABLE 2

Frequency MHz	Wavelength air/tissue (cm)	Dielectric constant	Depth of penetration (cm)
100	300/10.6	7.45	60.4
200	150/59.7	5.95	39.2
300	100/41	5.7	31.1
433	69.3/28.8	5.6	26.2
750	40/16.8	5.6	23
915	32.8/13.7	5.6	17.7
1,500	20/8.41	5.6	13.0
2,450	12.2/5.21	5.5	11.2
3,000	10/4.25	5.5	9.74
5,000	6/2.63	5.5	6.67
5,800	5.17/2.29	5.05	5.24
8,000	3.75/1.73	4.7	4.61
10,000	3/1.41	4.5	3.39

Characteristics of electomagnetic radiation wave propagation in low water content tissue (e.g., fat and bone) at various frequencies. Adapted from Baranski and Czerski at 50.

TABLE 3

POPULATION EXPOSURE RESULTS IN 15 CITIES

CITY	MEDIAN EXPOSURE (uW/cm^2)	PERCENT OF POPULATION Exposed <$1uW/cm^2$
ATLANTA	0.016	99.20%
BOSTON	0.018	98.50%
CHICAGO	0.0020	99.60%
DENVER	0.0074	99.85%
HOUSTON	0.011	99.99%
LAS VEGAS	0.012	99.10%
LOS ANGELES	0.0048	99.90%
MIAMI	0.0070	98.20%
NEW YORK	0.0022	99.60%
PHILADELPHIA	0.0070	99.87%
PORTLAND	0.020	99.70%
SAN DIEGO	0.010	99.85%
SAN FANCISCO	0.0020	97.66%
SEATTLE	0.0071	97.20%
WASHINGTON D.C.	0.009	97.20%
ALL CITIES	0.0048	99.44%

Table 4. Radiofrequency Levels in Tall Buildings That Are Located Close to FM and TV Antennas

Location	Power Density (uW/cm^2) FM	TV	TOTAL
EMPIRE STATE BUILDING (1)			
86th Floor Observatory	15.2		
102nd Floor Observatory			
Near Window	30.7	1.79	32.5
Near Elevator	1.35		
WORLD TRADE CENTER (1)			
107th Floor Observatory	0.10	1.10	1.20
Roof Observatory	0.15	7.18	7.33
PAN AM BUILDING			
54th Floor	3.76	6.52	10.3
ONE BISCAYNE TOWER (2)			
26th Floor	7		
30th Floor	5		
34th Floor	62		
38th Floor	97		
Roof (shielded area)	134		
Roof	148		
SEARS BUILDING (3)			
50th Floor	32	34	66
Roof	201	29	230
FEDERAL BUILDING (3)			
39th Floor	5.7	.73	6.5
HOME TOWER (4)			
10th Floor	18		
17th Floor	0.2		
Roof	119		
Roof	180		
MILAM BUILDING (5)			
47th Floor	35.8	31.6	67

(1) New York (3) Chicago (5) Houston
(2) Miami (4) San Diego

TABLE 5

CUMULATIVE POPULATION EXPOSURE FOR 15 U.S. CITIES (54-900MHz)

POWER DENSITY (uW/cm^2)	CUMULATIVE PERCENT OF POPULATION
1.0	99.4
0.5	98.8
0.2	97.0
0.1	94.7
0.05	91.4
0.02	82.4
0.01	68.7
0.005	49.5
0.002	19.5

Electrical Field Strength In and Around Radio-Equipped Vehicles

Frequency, MHz	Transmitter Power, W	Vehicle Type	Field Strength, V/m
27.075	5	Sedan	2-7
27.610	80[a]	Sedan	21-25[b]
40.27	110	Sedan	10-190
40.27	110	Sedan	75-368[b]
40.27	110	Tractor-trailer	5-475
41.31	100	Compact	5-106[c]
41.31	100	Pickup truck	7-165[c]
162.475	110	Sedan	8-201
164.45	60	Sedan	5-52
164.45	60	Station wagon	5-64[c]
164.45	60	Van	5-95[c]

[a] Legal power is 5W, assuming 80% efficiency (4W); illegal power used with special authorization of the Interagency Radio Advisory Committee.

[b]Vehicle was placed on an electrically grounded plane.

[c]Calculated from the reported electrical energy density as given in original report.

(adapted from National Academy of Sciences,"Analysis of the Exposure Levels and Potential Biologic Effects of the Pave Paws Radar System", 1979)

Table 6

TABLE 7

Electric and Magnetic Fields at Operator Positions near Industrial Radio Frequency Sources.

Source	Power (kw)	Freq. (MHz)	Field Strength[a] Electric (V/m)	Magnetic (A/m)
Fiber Dryer	20	41	319	13.2
Glue Dryer	20	27	221	1.0
Heat Sealer	10	15	831	.5
Heat Sealer	2	22	493	12.1
Heat Sealer	4	30	973	.4

Leakage from Diathermy Applicators[a]

Applicator Type	Leakage (mW/cm^2) Normal[b]	Maximum[c]
Burdick "B"	10.4	35.5
Burdick "E"	19.0	44.0
Transco[d]	-	0.2

a. Determined using a planar phantom of muscle equivalent material with a 1 cm simulated fat layer.

b. Determined using net power recommended by manufacturer for lower back treatments, 45 and 70 Watts net power for types "B" and "E", respectively.

c. Extrapolated for "effective treatment" conditions as defined by Lehmann et al. (33), i.e., an absorption rate of 235 W/kg.

d. Contact applicator.

TABLE 8

SPECIES	POWER DENSITY (mW/cm^2)	EXPOSURE TIME (min)	FREQUENCY (MHz)	TEMPERATURE INCREASES (°C)
DOG	330	15	200	5°
DOG	220	21	200	4°
DOG	165	270	2,800	4-6°
RABBIT	300	25	2,800	6-7.5%
RABBIT	165	30	200	6-7%
RABBIT	100	103	2,800	4-5%
RAT	400	13-14	10,000	7%
RAT	300	15	3,000	8-10%
RAT	300	15	24,000	5%
RAT	100	25	3,000	6-7%
RAT	40	90	3,000	--

Power Densitites and exposure times until thermal death in various animal species at various frequencies (from Baranski and Czerski at 79).

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(Note: The following list of sources is limited to those which provided a particularly extensive background into, or discussion of, the issues involved. Other, more limited, sources used in preparation of this paper are referenced in the footnotes.)

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